1.0 STUDY PERSPECTIVE AND SUMMARY

Central California is a complex region from an air quality and meteorological perspective, owing to its proximity to the Pacific Ocean, its diversity of climates, and its complex terrain. As a result of progressively more stringent controls on emissions of reactive organic gases and oxides of nitrogen, the frequency and intensity of excessive ozone concentrations in central and northern California have been significantly reduced despite rapid increases in population, commercial activities and vehicle miles traveled. For example, the average annual maximum hourly ozone concentrations have declined by 40, 21, and 30 percent from 1980 to 1997 in the San Francisco Bay Area, Sacramento Valley, and San Joaquin Valley air basins, respectively. The average annual exceedances of the federal 1-hour ozone standard (0.12 ppm) in the San Francisco Bay Area declined from 11 in 1980 to 4 in 1997, from 21 to 10 in the Sacramento Valley Air Basin and from 58 to 41 in the San Joaquin Valley Air Basin. While progress has been made toward attainment of the 1-hour ozone standard, it continues to be exceeded frequently in central California, and the prediction of attainment for the San Joaquin Valley by 1999, based on modeled forecast of emissions in 1994 (SJVUAPCD, 1994), has not been acheived.

Retrospective analyses of ozone (O_3) data (details in Section 2) have also shown varying progress toward attainment of ozone standards within northern and central California with greater reductions in ozone within coastal urban areas than in the Central Valley. In addition, the data show larger downward trends in 1-hour-average peak O_3 concentrations [1] and less progress in reducing the frequency of exceedances of the state 1-hour standard (0.09 ppm) and the pending federal 8-hour ozone standard [2]. In addition to areas that are currently in nonattainment of the 1-hour ozone standard, several areas in central and southern Sierra Foothills and northern Sacramento Valley that are now in compliance of the 1-hour standard are also expected to become nonattainment for the 8-hour standard. The state 1-hour and pending federal 8-hour ozone standards will require a reappraisal of past strategies that have focused primarily on addressing the urban/suburban ozone problem to one that considers the problem in a more regional context. Although the recent court action prohibits EPA from enforcing the 8-hour ozone standard, the ruling did not remove the standard. Pending the likely appeal by EPA and its ultimate outcome, the current 1-hour ozone standard continues to apply in areas that have not attained the standard.

1.1 Introduction

The Central California Ozone Study (CCOS) is intended to provide another milestone in the understanding of relationships among emissions, transport, and ozone standard exceedances, as well as to facilitate planning for further emission reductions needed to attain state and federal ozone standards. The CCOS is being proposed to gather aerometric and emissions databases for modeling and to apply air quality models for the attainment demonstration portion of the SIP for the federal 8-hour and state 1-hour ozone standards. CCOS is an integrated effort that includes air quality and meteorological field measurements, emissions characterization, data analysis and

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[1] In this report, the term concentration refers to mixing ratios by volume.

[2] The new standard will be attained when the 3-year average of the annual 4th highest daily maximum 8-hour concentration is less than or equal to 0.08 ppm.

air quality modeling. The modeling domain for CCOS will cover all of central California and most of northern California, extending from the Pacific Ocean to east of the Sierra Nevada and from Redding to the Mojave Desert. The selection of this study area reflects the regional nature of the state 1-hour and federal 8-hour ozone exceedances, increasing urbanization of traditionally rural areas, and a need to include all of the major flow features that affect air quality in central California in the modeling domain. The CCOS field measurement program will be conducted in the summer of 2000 in conjunction with the California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS), a major study of the origin, nature and extent of excessive levels of fine particles in central California (Watson et al., 1998).

The CCOS is directed by a technical committee that comprises staff from the California Air Resources Board (ARB), U.S. Environmental Protection Agency (EPA), the California Energy Commission (CEC), local air pollution control agencies, industry, and other sponsoring organizations with technical input from a consortium of university researchers in California and the Desert Research Institute (DRI). The CCOS plan consists of this field study plan (Volume I) and a field operations plan and protocol (Volume II), which will be available by April, 2000. These documents correspond to the two phases of the planning process for CCOS. Parallel efforts are also underway to develop a broad conceptual model of ozone formation in central California based on SARMAP[3] and other relevant studies and a "comprehensive" study plan that addresses the long-term research needs related to the ozone problem in central California (Roth, 1999a and 1999b).

This CCOS field study plan describes the goals and technical objectives that will be addressed by the study and describes alternative experimental, modeling, and data analysis approaches for addressing the study objectives. This introductory section provides an overview of the study, which includes the background and rationale for the proposed study, statements of study goals and technical objectives, and a summary of the proposed field measurements and subsequent modeling and data analysis. Chapter 2 presents a summary of the current knowledge of the relationship among meteorology, emissions, chemical and physical transformation, and ozone concentrations in northern and central California. It also reviews the results from prior SAQM[4] modeling by ARB, and identifies the remaining uncertainties and their implications for the design of the CCOS field measurement program. Section 3 describes the requirements for the modeling and data analysis approaches that are proposed to address CCOS technical objectives. Section 4 specifies the CCOS measurements that are recommended to meet the requirements of modeling and data analysis. It considers the merits of alternative measurement approaches and explains the rationale and criteria for measurement decisions. Details of the measurements are contained in three appendices. Appendix A describes the existing meteorological and air quality measurement networks and details of the supplemental measurements proposed for CCOS (e.g., measurement method, precision, and accuracy). Appendix A1 provides a list of volatile organic compounds that are recommended for identification and quantification as part of the chemical characterization of ozone precursors. Appendices B and C describe the required quality assurance and data management activities for the study, respectively. Appendix D describes a special study of ozone formation in elevated

[3] San Joaquin Valley Air Quality Study and Atmospheric Utility Signatures, Predictions and Experiments Regional Model Adaptation Program

[4] SARMAP Air Quality Model

plumes. Section 5 provides the corresponding budget estimates and Section 6 defines the program management and schedule.

This third version of the CCOS field study plan is a product of regular meetings of the CCOS Technical Committee and Working Groups over the past six months with input from local air pollution control districts, academia, and industry reviewers on two earlier versions of the plan (released on 6/11/99 and 9/7/99). The current plan serves as the basis for contracts with measurement groups and for developing the operations plan and protocols for the field study in summer 2000.

1.2 CCOS Goals and Technical Objectives

The CCOS has the following goals.

1. Obtain suitable aerometric and emission databases to update, evaluate, and improve model applications for representing urban and regional-scale ozone episodes in central and northern California to meet the regulatory requirements for the state 1-hour and pending federal 8-hour ozone standards.

2. Determine the contributions of transported and locally generated ozone and the relative benefits of volatile (VOC) and nitrogen oxide (NOx) emission controls in upwind and downwind areas. Assess the relative contributions of ozone generated from emissions in one air basin to federal and state exceedances in neighboring air basins.

These goals are to be met through a process that includes analysis of existing data; execution of a large-scale field study to acquire a comprehensive database to support modeling and data analysis; analysis of the data collected during the field study; and the development, evaluation, and application of an air quality simulation model for northern and central California. Although air quality simulation modeling may be used to address both CCOS goals, past experience has demonstrated the need for thorough diagnostic analyses and corroborative data analysis to assess the reliability of model outputs.

The study design and experimental approach for CCOS are defined in terms of specific technical objectives. These objectives fall into four categories: (A) planning and preparation; (B) emission inventory development, (C) modeling, and (D) data analysis. A number of tasks are required to meet each of the technical objectives. These tasks are listed in this section and are described in greater detail in Section 3 (data requirements) and Section 4 (field measurement program).

1.2.1 Objectives A - Planning and Preparation for the CCOS Field Study

Objective A-1. Develop a technically and scientifically defensible experimental design based on the goals and objectives of the sponsoring organizations and current conceptual understanding of the chemical and meteorological conditions that are conducive to violations of the state 1-hour and federal 8-hour ozone standards in central California.

a. Update current bibliography, review and summarize the literature on emissions, meteorology, ozone formation, and transport in central California, and identify gaps in current knowledge with respect to the questions posed.

b. Summarize existing monitoring data in central California with respect to locations and frequency of exceedances of the threshold value for the state 1-hour and pending federal 8-hour ozone standards.

c. Review and evaluate past SIP modeling projections of air quality for the San Francisco Bay Area, the San Joaquin Valley, and the Sacramento Valley to ascertain the causes of biases in estimates of air quality improvements.

d. Formulate specific questions to be answered by the CCOS field measurement program. Prioritize these questions according to their importance in meeting the objectives of compiling a database for grid-based modeling and improving understanding of the atmospheric processes that affect surface and aloft ozone concentrations.

e. Identify meteorological scenarios related to exceedances of the 8-hour ozone standard and specify the characteristics of episodes for which monitoring would be sought as part of CCOS, and outline a strategy for forecasting these episodes based on existing data acquisition.

f. Survey existing and planned quantitative modeling and data analysis approaches and determine the additional information needed to improve, evaluate, and apply them.

g. Summarize and evaluate existing, long-term measurement networks in central California. Consider the need for supplemental measurements of surface and aloft concentrations of ozone, ozone precursors and reaction products and reactive intermediates to adequately characterize their three-dimensional distribution within the CCOS modeling domain. Consider alternative measurement methods with respect to temporal and spatial resolution, precision and accuracy, and cost.

h. Review and determine the applicability of existing surface and upper-air meteorological measurements (e.g., ARB, APCD, and military) and planned CRPAQS meteorological measurements toward achieving the technical objectives of CCOS. Consider supplemental surface and upper-air meteorological measurements needed to adequately characterize the main air flow patterns in the CCOS domain.

i. Evaluate potential measurement methods with respect to required averaging times, duration, detection limits, accuracy, precision, validity, and cost-effectiveness. Determine which observables can be measured continuously and which require integrated samples that are submitted to off-site laboratory analysis. Relate each measurement to its intended use in a modeling and/or data analysis activity.

j. Define steps for appropriate quality control/quality assurance in order to produce data of specified completeness, validity, accuracy and precision. Articulate the appropriate levels of funding required for the necessary components of quality control/quality assurance (QC/QA), database management and data archival.

k. Estimate costs for each element of the conceptual plan and summarize the rationale and justification for their inclusion in the final network design in order to facilitate consideration by the CCOS Technical Committee of program options and tradeoffs.

l. Prepare and post the program plan, in PDF format, to the CCOS web site.

Objective A-2. Prepare the CCOS operational plan and field operations protocol, make contractual arrangements with measurement groups, and conduct preliminary evaluations of measurement methods and forecast protocol.

a. Prepare and issue requests for proposals for CCOS field measurements, as necessary, and make contractual arrangements with measurement groups. Identify coordinators for quality assurance and data management.

b. Evaluate the accuracy, precision and validity of measurement methods that have not been sufficiently tested under either laboratory or field conditions. Such methods include continuous NO_2 and PAN measurement by gas chromatography (GC)/Luminol and continuous HCHO measurements. Assemble and evaluate the accuracy and precision of an automated GC/ion trap mass spectrometry (MS) and develop a calibration library for identification and quantitation of VOC species of interest.

c. Arrange for the acquisition of new air quality measurement sites. Ensure compliance with applicable siting criteria in the network design plan. Document the site with GPS data, digital images, and perform a video survey of each new site and enter site information into the field operations protocol. Determine the needs and costs for permits, indemnification/insurance requirements, compliance with environmental and safety laws, water, power, air conditioning, and sanitary facilities, and additional structures to accommodate added sampling equipment.

d. Set up a forecast system to identify potential study days that meet preselected criteria and maintain daily contact with the study management for selection of sampling days. Design a protocol for handling the scheduling of intensive measurement periods. Specify the episode forecasting method that will be implemented and identify how go/no go decisions will be made and disseminated to project participants.

e. Prepare an operational program plan and field operations protocol that specifies the details of the field measurement program that will allow the study plan to be executed with available resources. It identifies measurement locations, observables, and monitoring methods. It specifies data management and reporting conventions and outlines the activities needed to ensure data quality. The field operations protocol is a short document that serves as the guide for those in the field. It is a concise overview of the field study, enumerating the most pertinent information needed by those conducting the measurements. Post the operational plan and field operations protocol, in PDF format, to the CCOS web site by April 2000.

f. Conduct a workshop in May 2000 in Sacramento with ARB and district staff, measurement contractors, and other study participants to orient them to the elements in the plan and their responsibilities as members of the project team. Review the draft field operations protocol with the project team, and reconcile any discrepancies between the protocol and measurements planned by study participants. Ensure that potential cross-contamination between measurements is eliminated. Confirm schedules and protocols, and identify potential logistical problems and develop appropriate action plans for their resolution.

1.2.2 Objectives B - Emission Inventory Development

Objective B-1. Prepare day-specific, hourly, gridded emission inventories that cover each day of the ozone episodes captured during the CCOS field study.

a. Develop a "fast-track" spatially and temporally resolved inventory of emission estimates of ROG, NOx, and CO for the CCOS domain for summer 2000 for preliminary modeling.

b. Update the "fast-track" with day-specific information collected during the CCOS study (see Objective B-2).

c. Project the effects of future activity and alternative controls on emission estimates and develop a spatially and temporally resolved inventory for future year simulation.

Objective B-2. Collect day-specific emissions data to update the "fast-track" inventory to more accurately determine the spatial and temporal distribution of emissions from elevated point sources, motor vehicles and other area sources.

a. Integrate transportation data for CCOS domain and run DTIM for entire modeling domain. Create gridded, hourly emission estimates of NOx, TOG, CO and PM for on-road mobile sources.

b. Develop base year and future year gridding surrogates for spatial distribution of stationary area source categories.

c. Compile biomass and emission factor data for major plant species in the Central Valley and Bay Area for use in GIS-based biogenic inventory for the CCOS modeling domain.

d. Collect day-specific emission data for wildfires, controlled burns, and agricultural burns.

e. Develop point and area source emission inventories for smaller air pollution control districts.

f. Obtain hourly estimates of NOx emissions from major point sources to supplement the "fast-track" inventory during potential modeling episodes.

1.2.3 Objectives C - Preparation, Execution and Evaluation of Air Quality Simulation Modeling System

Objective C-1. Apply air quality models for the attainment demonstration portion of the SIP for the proposed 8-hour and state 1-hour ozone standards.

a. Select the most suitable modeling systems (for meteorology, emissions, and air quality) for representing photochemical air pollution in central and northern California. At least one of the models selected should have the ability to simulate both ozone and fine particles. Simulations with that model could be applied to both CRPAQS and CCOS. This will facilitate integration of results across both studies.

b. Analyze the data collected during the CCOS field measurement program and select a minimum of three ozone episodes to simulate.

c. Specify model domain boundaries, boundary conditions, initial conditions, chemical mechanisms, aerosol module, plume-in-grid module, grid sizes, layers, and surface characteristics.

d. Identify performance evaluation methods and performance measures, and specify methods by which these will be applied.

e. Evaluate the results of the meteorological model (see Section 3.2.1 for list of evaluation checks).

f. Perform operational evaluation of the air quality model (see Section 3.2.3)

g. Evaluate and improve the performance of emissions, meteorological, and air quality simulations. Apply simulation methods to estimate ozone concentrations at receptor sites and to test potential emissions reduction strategies.

h. Identify the limiting precursors of ozone and assess the extent to which reductions in volatile organic compounds and nitrogen oxides, would be effective in reducing ozone concentrations.

Objective C-2. Determine the relative contributions of ozone generated from emissions in one basin to federal and state exceedances in neighboring air basin.

a. Characterize the structure and evolution of the boundary layer and the nature of regional circulation patterns that determine the transport and diffusion of ozone and its precursors in northern and central California.

b. Identify and describe transport pathways between neighboring air basins, and estimate the fluxes of ozone and precursors transported at ground level and aloft under differing meteorological conditions. Reconcile results with flux plane measurements.

c. Determine the contribution of ozone generated from emissions in one basin to federal and state exceedances in neighboring air basin through emission reduction sensitivity analysis.

Objective C-3. Provide improve understanding of the role of thermal power plant plumes in contributing to regional air quality problems in central California.

a. Conduct measurements during CCOS Intensive Operational Periods (IOPs) in plumes from one or more power plants to allow reactive plume or plume-in-grid model to be evaluated.

b. Provide operational evaluation of a state-of-the-science reactive plume model component using data collected during the CCOS field study.

c. Using the modeling system developed by CCOS, provide a technical analysis appropriate to support the development of interbasin/intrabasin as well as interpollutant offset rules that could be applied to the central California region.

d. Run model simulations to estimate the air quality implications of different energy policies.

Objective C-4. Assess the reliability associated with air quality model inputs and formulation, and reconcile model results with observation-based and other data analysis methods.

a. Perform diagnostic evaluation of model results (see Section 3.2.3)

b. Quantify the uncertainty of emissions rates, chemical compositions, locations, and timing of ozone precursors that are estimated by emission models.

c. Quantify the uncertainty of meteorological and air quality models in simulating atmospheric transport, transformation, and deposition.

1.2.4 Objectives D - Data Analysis

Objective D-1. Determine the accuracy, precision, validity, and equivalence of CCOS field measurements.

a. Evaluate the precision, accuracy, and validity of criteria pollutant data from routine monitoring stations.

b. Evaluate the precision, accuracy, and validity of PAMS and CCOS supplemental VOC measurements and nitrogenous species measurements.

c. Evaluate the precision, accuracy, validity, and equivalence of routine network and CCOS supplemental surface and upper-air meteorological data.

d. Evaluate the precision, accuracy, validity of data from instrumented aircraft and radiosonde/ozonesonde releases.

e. Evaluate the precision, accuracy, validity, and equivalence of routine and supplemental solar radiation data.

Objective D-2. Determine the spatial, temporal, and statistical distributions of air quality measurements to provide a guide to the database and aid in the formulation of hypotheses to be tested by more detailed analyses.

a. Examine average diurnal changes of surface concentration data during episodic and non-episodic periods.

b. Examine spatial distributions of surface concentration data.

c. Examine statistical distributions and relationships among surface air quality measurements.

d. Examine vertical distribution of concentrations from airborne measurements.

e. Examine the spatial and temporal distribution of solar radiation.

Objective D-3. Characterize meteorological transport phenomena and dispersion processes.

a. Examine the mechanisms for the movement of air into, out of, and between the different air basins in both horizontal and vertical directions.

b. Determine occurrence, spatial extent, intensity, and variability of phenomena affecting horizontal transport (low-level jet, slope flows, eddies, coastal meteorology and flow bifurcation) and vertical transport (convergence and divergence zones).

c. Characterize the depth, intensity, and temporal changes of the mixed layer and characterize mixing of elevated and surface emissions.

Objective D-4. Reconcile emissions inventory estimates with ambient measurements and "real-world" source measurements.

a. Compare proportions of species measured in ambient air and those estimated by emission inventories for reactive and nonreactive species.

b. Estimate source contributions by Chemical Mass Balance using measured and predicted ambient VOC composition.

c. Conduct on-road remote sensing measurements of CO, HC, NOx and (PM if available) in Sacramento, Fresno, and the San Francisco Bay Area, and evaluate the effects of cold-starts, grade and geographic distribution of high-emitting vehicles.

d. Reconcile on-road motor vehicle emission inventory estimates and fuel-based emissions estimates.

e. Determine effects of meteorological variables on emissions rates.

f. Determine the detectability of day-specific emissions (e.g., fires) and variations in emissions between weekday and weekend.

Objective D-5. Characterize pollutant fluxes between upwind and receptor areas. Examine the orientations, dimensions, and locations of flux planes by using aircraft spiral and traverse data, and ground-based concentration data for VOCs, NOx, and O_3 coupled with average wind speeds that are perpendicular to the chosen flux planes.

a. Define the orientations, dimensions, and locations of flux planes.

b. Estimate the fluxes and total quantities of selected pollutants transported across flux planes. Test following hypotheses: 1) whether there is significant local generation of pollutants; 2) whether there is significant dilution within or turbulent exchange through the top of the mixed layer; and 3) whether there is substantial transport or dilution owing to eddies, nocturnal jets, and upslope/downslope flows.

Objective D-6. Characterize chemical and physical interactions in the formation of ozone.

a. Examine VOC and nitrogen budgets as functions of location and time of day.

b. Reconcile the spatial, temporal, and chemical variations in ozone, precursor, and end-product concentrations with expectations from chemical theory.

c. Apply observation-based methods to determine where and when ozone concentrations are limited by the availability of NOx or VOC.

d. Identify the composition and location of one or more power plant plumes and their surrounding air aloft so that the dispersion and chemical evolution of the plume(s) can be inferred.

Objective D-7. Characterize episodes in terms of emissions, meteorology, and air quality and determine the degree to which each intensive episode is a valid representation of commonly occurring conditions and its suitability for control strategy development.

a. Describe each intensive episode in terms of emissions, meteorology, and air quality.

b. Examine continuous meteorological and air quality data acquired for the entire study period, and determine the frequency of occurrence of days which have transport and transformation potential similar to those of the intensive study days. Generalize this frequency to previous years, using existing information for those years.

Objective D-8. Reformulate the conceptual model of ozone formation in the study domain using the results yielded by the foregoing data analyses and modeling. Examine the formulation, assumptions, and parameters in mathematical modules in the air quality model with respect to their consistency with reality.

1.3 Basis for CCOS Field Measurement Program

In the development of this study plan, new analysis has been undertaken to complement past studies addressed in Section 2. In this summary, three investigations are described that were initiated to further understand the meteorological conditions that foster ozone formation and that influence the spatial distribution of ozone in central California (details in Section 2). First, nine years (1990-98) of ozone data from selected sites were compiled and examined for 1-hr and 8-hr ozone trends and to identify important features of the diurnal and hebdomadal (weekly) cycles of ozone. Second, a bottom-up statistical cluster analysis of daily-maximum ozone data was completed to objectively group high ozone days selected by local districts, and then to search for statistically significant differences in meteorological parameters among the clusters. Third, a top-down approach based on subjective classification of daily weather maps was compared to the observed air quality. Toward this end, a meteorological working group has been formed to generate, at a minimum, a small set of qualitative scenarios to aid in the development of the CCOS study plan, and to link these scenarios to objective analysis. These scenarios can then be used to guide forecasting of episodes, and to help distinguish between the types of episodes that may enhance ozone formation in specific sub-regions or different air basins within the proposed study area.

1.3.1 Analysis of Past Ozone Data

A 126-site, 9-year (1990-98) subset of ozone data was selected from the ARB database as described in Section 2.3.1. Breakdowns by site and air basin were examined for 1-hour and 8-hour annual maximum of daily maxima, number of exceedance days per year, seasonal occurrences by month (May-Oct), and the hebdomadal cycle of exceedances. As expected, sites downwind of metropolitan areas have the greatest number of exceedances per year. These are Folsom, Auburn, Cool, and Placerville downwind of Sacramento, Arvin and Edison downwind of Bakersfield, Parlier and Maricopa downwind of Fresno, and Livermore downwind of the major Bay Area cities. Overall, southern San Joaquin Valley has the worst air quality in the CCOS region. The CCOS surface sites are located to measure the chemical transformations taking place with downwind transport.

Seasonal occurrences of ozone exceedances were dominated by July and August with the lower numbers in June and September being approximately equal to each other. The July-August time frame for CCOS intensives is justified. A weekend/weekday effect was found for rural, suburban and urban sites, although rigorous statistical significance of the effect was not pursued and is part of other on-going efforts.

1.3.2 Cluster Analysis of High Ozone Days

Ozone data from ozone seasons 1996-98 are employed to determine groupings of spatial patterns on several very high ozone days selected by the local air quality districts. Despite some differences in the 8-hour and 1-hour results that are still being examined in the Meteorological Working Group, three clusters are found for both 1-hour and 8-hour exceedances:

Cluster 1 - The San Francisco Bay Area (SFBA) has its highest basin-wide ozone values, though still less in absolute magnitude than San Joaquin Valley. This cluster is characterized by the weakest sea breeze (lowest west-to-east component through Carquinez Strait), and the lowest Oakland inversion base heights. Among the cluster days, North Central Coast ozone is also highest during Cluster 1.

Cluster 2 - The San Joaquin Valley (SJV) has its highest basin-wide values while the Bay Area and Sacramento Valley are relatively cleaner. A stronger sea breeze, relatively to Cluster 1, keeps the pollutants moving through the Bay Area and the Sacramento Valley, but may increase transport into the SJV. Among the cluster days, Mountain Counties ozone is lowest during Cluster 2

Cluster 3 – Sacramento Valley (SV) has its highest basin-wide ozone values, as does the Mountain Counties Air Basin. As with Cluster 2, a stronger sea breeze is present, relative to Cluster 1, but surface temperatures in Sacramento Valley are significantly higher, indicating less and/or later intrusion of the sea breeze, allowing more time for photochemistry before evening transport to the Mountain Counties.

Figure 1.3-1 shows the average ozone for each cluster and for all 42 cluster days (Cluster 1- 22 days, Cluster 2 – 12 days, and Cluster 3 – 8 days). Days were selected from 1996-98 high-ozone episodes identified by local districts (see Section 2.5.4.3). Differences in average ozone concentrations among the three clusters are statistically significant (at 95% confidence level) for both SFBA and SV. However, for SJV, none of the clusters are significantly different due to less marine air intrusion into SJV. This analysis shows the importance of the sea breeze in determining spatial distribution of ozone accumulation. When the sea breeze is inhibited, higher ozone levels occur throughout the study area, including the coastal regions. The San Joaquin Valley shows the least variation among the clusters owing to the combined effect of topography and greater distance from the coast, while Sacramento Valley shows more variation due to potential for greater influence of the marine intrusion.

Figures 1.3-2 through 1.3-7 illustrate the differences in the spatial patterns of ozone concentrations for these three clusters, for both 1hr (Figures 1.3-2, 4 and 6) and 8hr (Figures 1.3-3, 5, and 7) ozone maximums. Each figure displays the daily ozone maximum from 126 monitoring stations throughout the entire study region. More discussion is presented in Sections 2.3, 2.5 and 2.7, but some features are noted here.

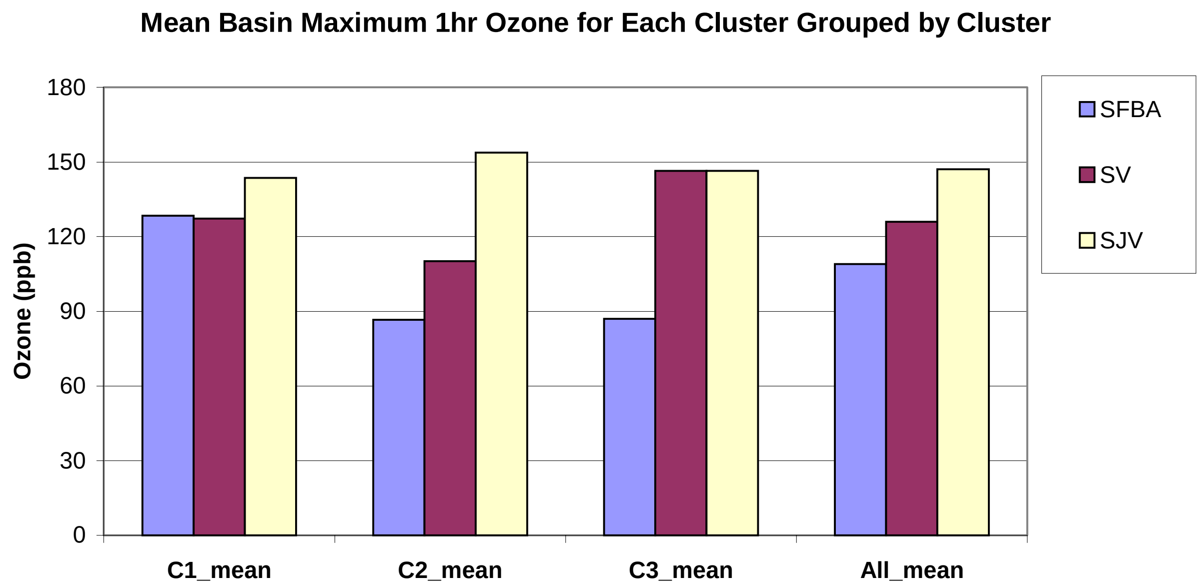
- The SFBA had ozone on a par with the SJV (147 ppb at Concord and 145 ppb at Clovis in the SJV) on August 12, 1998, a Cluster 1 day. The hexagon and large circles represent exceedances of the 1hr standard. The upper Sacramento Valley was relatively clean with no state 1-hr or Federal 8-hr exceedances.

- On August 30, 1996, a Cluster 2 day, the SFBA and Sacramento Valley (SV) were relatively clean, but San Andreas registered a 138 ppb on the southeastern edge of the clean zone, whereas the northern Mountain Counties were clean like the SV. Arvin and Edison experienced 156 and 163 ppb ozone, respectively.

- An interesting feature on August 14, 1998, a Cluster 3 day, is the high 8-hr ozone values in the north Sacramento Valley. There were 8-hr exceedances downwind of Sacramento, but even higher 8-hr values of 110 ppb were present in Redding.

1.3.3 Meteorological Scenarios by Weather Map Analysis

The development of a conceptual model for ozone formation is aided by identification of meteorological scenarios that foster the formation, accumulation and transport of ozone (see Sections 2.3, 2.5 and 2.7). An idealized set of meteorological scenarios would be distinct from one another. Each scenario should be linked to a set of commonly measured observables, like routine meteorological and air quality data, to increase the success rate of go/no-go decisions based on weather forecasts.



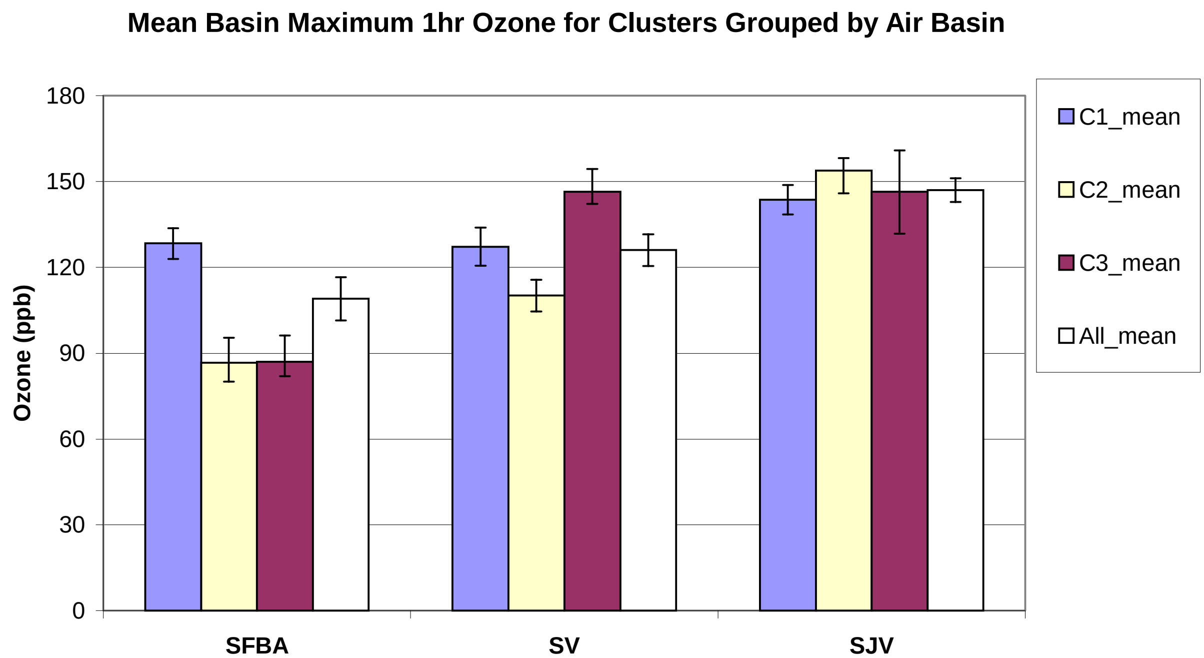


Figure 1.3-1. Mean basin maximum[5] 1-hour ozone for each cluster grouped by cluster and grouped by air basin.

[5] Average ozone for clusters and for all 42 cluster days (Cluster 1- 22 days, Cluster 2 – 12 days, and Cluster 3 – 8 days). Days were selected from 1996-98 high-ozone episodes identified by local districts (see Section 2.5.4.3). Differences for SFBA are statistically significant for all three clusters and each is different from the mean. Differences for SV are statistically significant for all three clusters, but only 2 and 3 differ from the mean. None of the clusters are significant for SJV due to less sea breeze penetration over the surrounding topography.

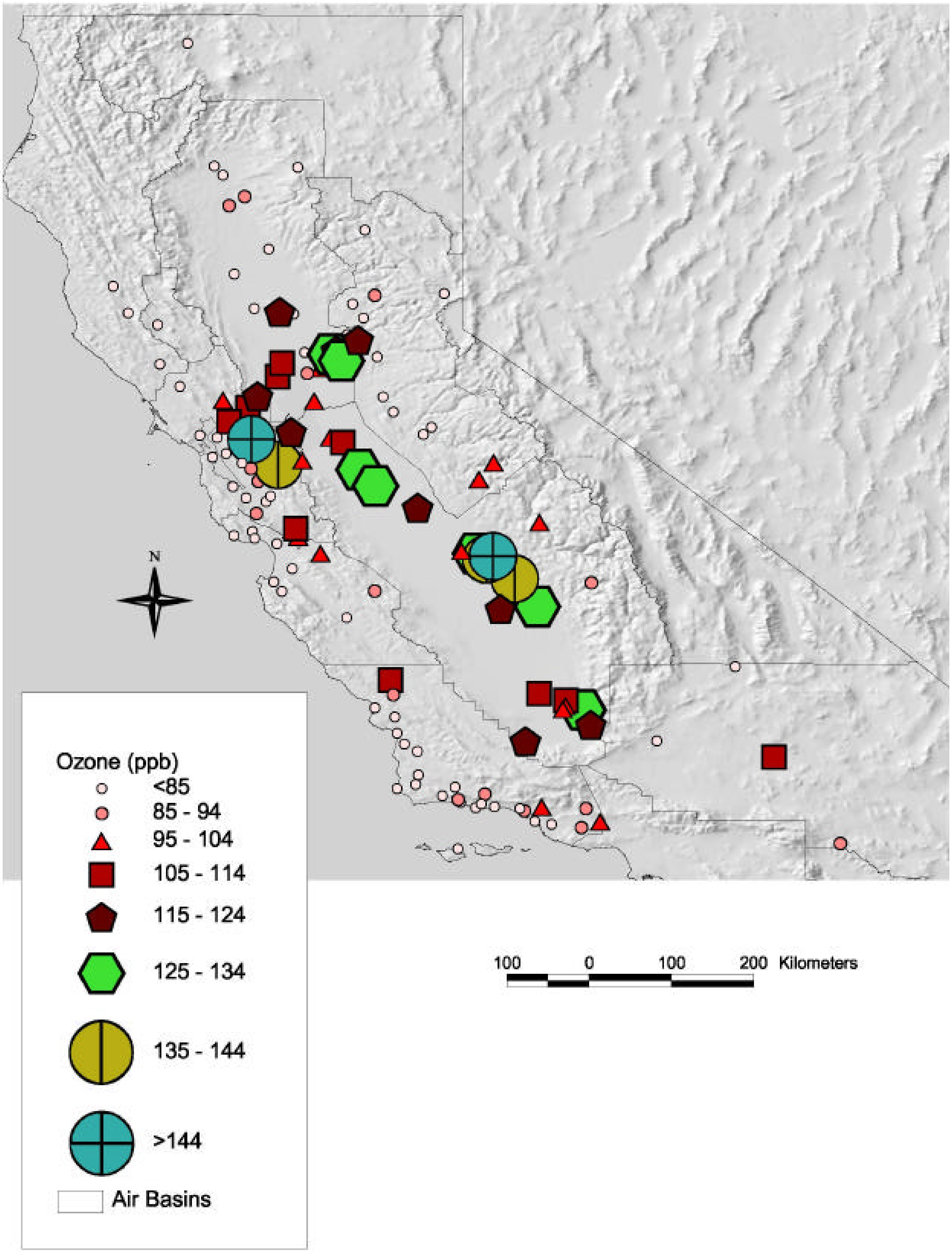


Figure 1.3-2. Maximum 1hr ozone for 126 monitoring stations on 8/12/98, a Cluster 1 Day.

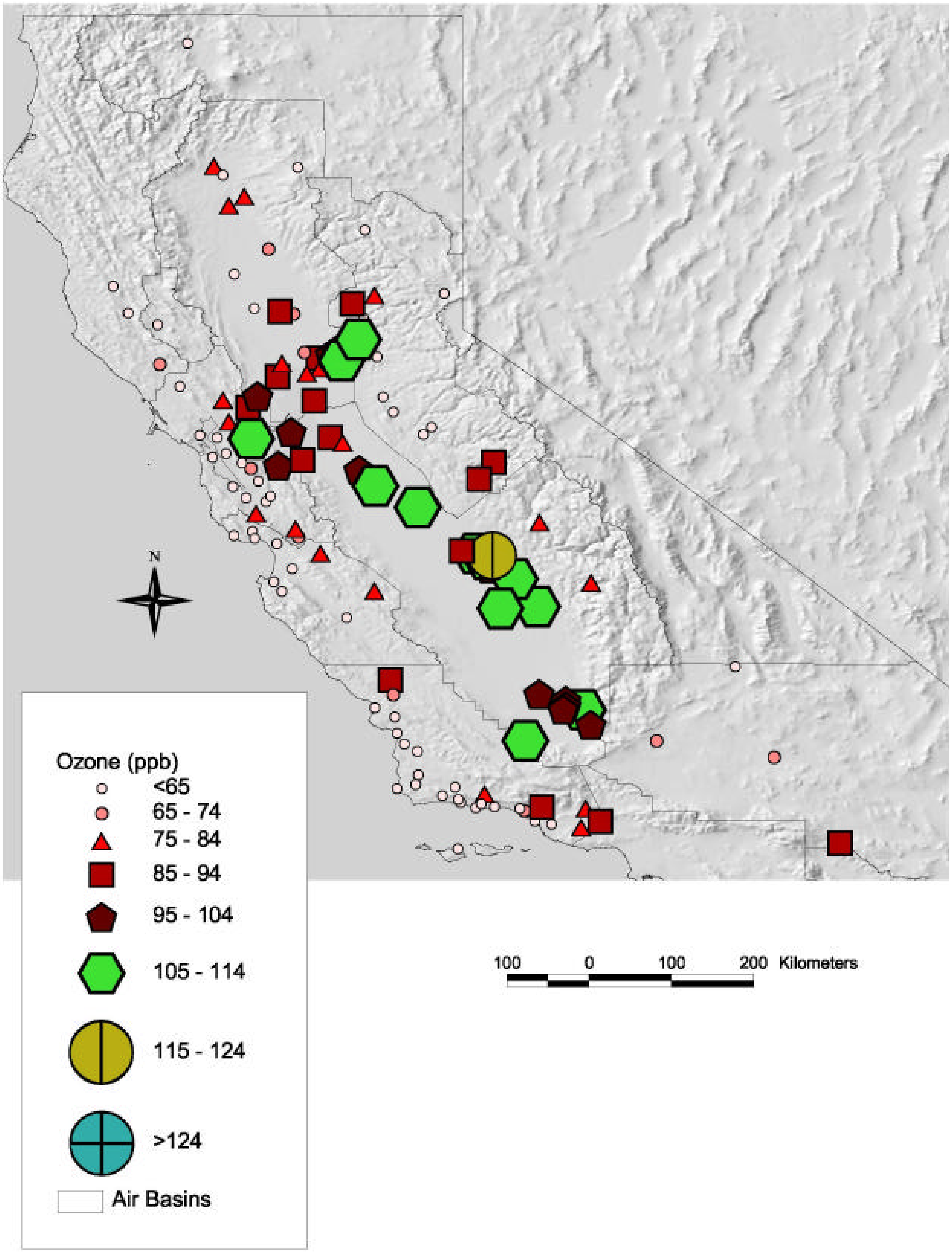


Figure 1.3-3. Maximum 8hr ozone for 126 monitoring stations on 8/12/98, a Cluster 1 Day.

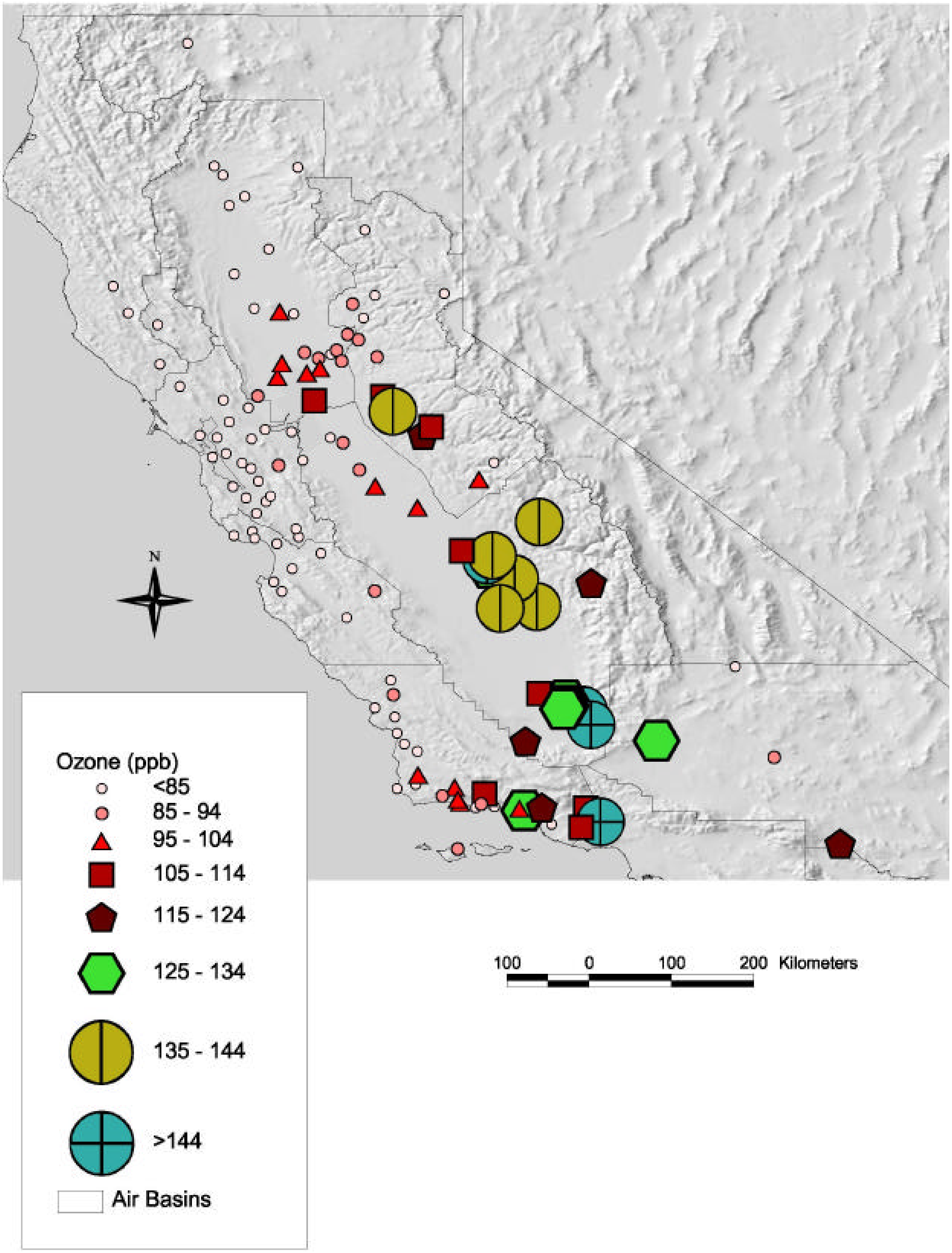


Figure 1.3-4. Maximum 1hr ozone for 126 monitoring stations on 8/30/96, a Cluster 2 Day.

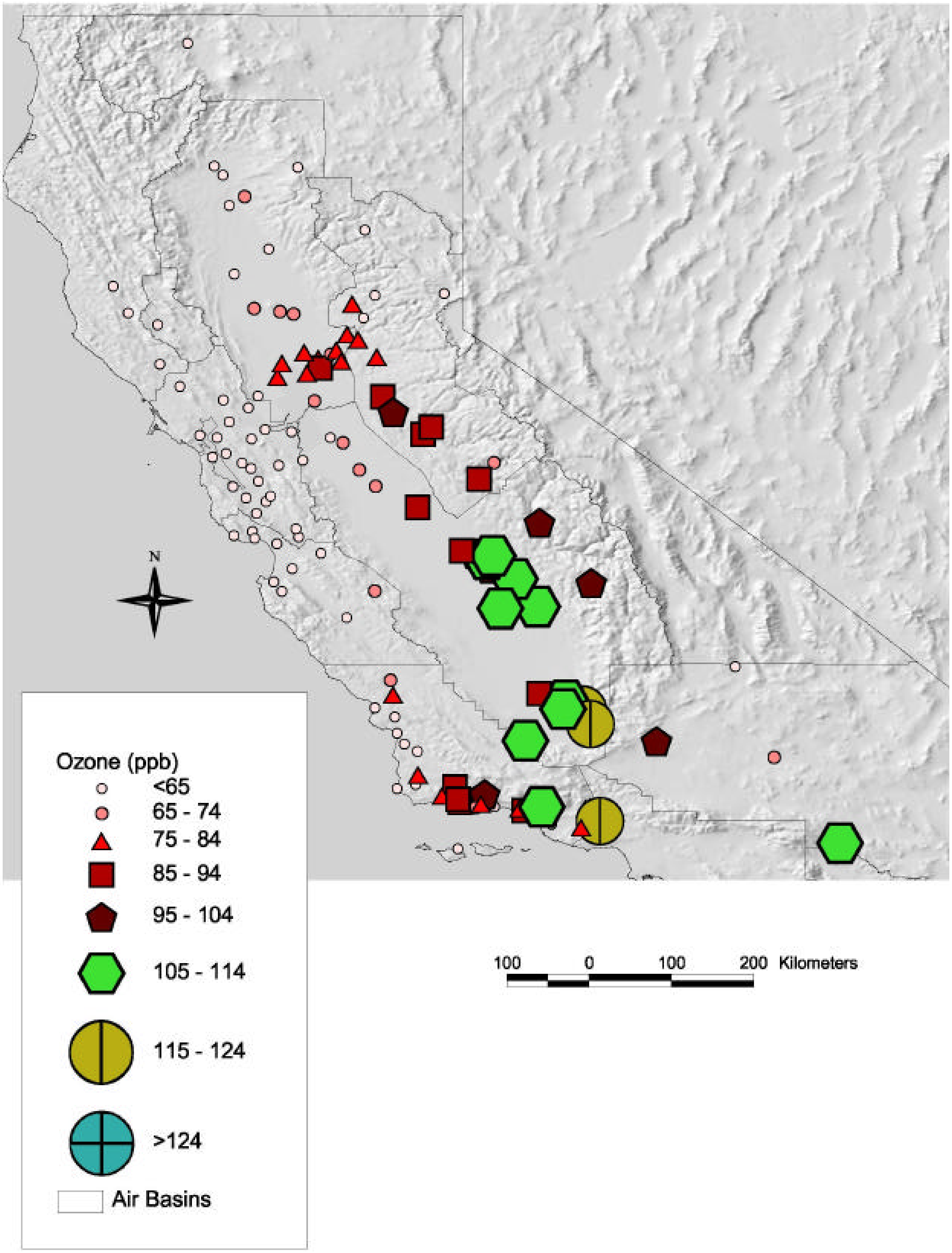


Figure 1.3-5. Maximum 8hr ozone for 126 monitoring stations on 8/30/96, a Cluster 2 Day.

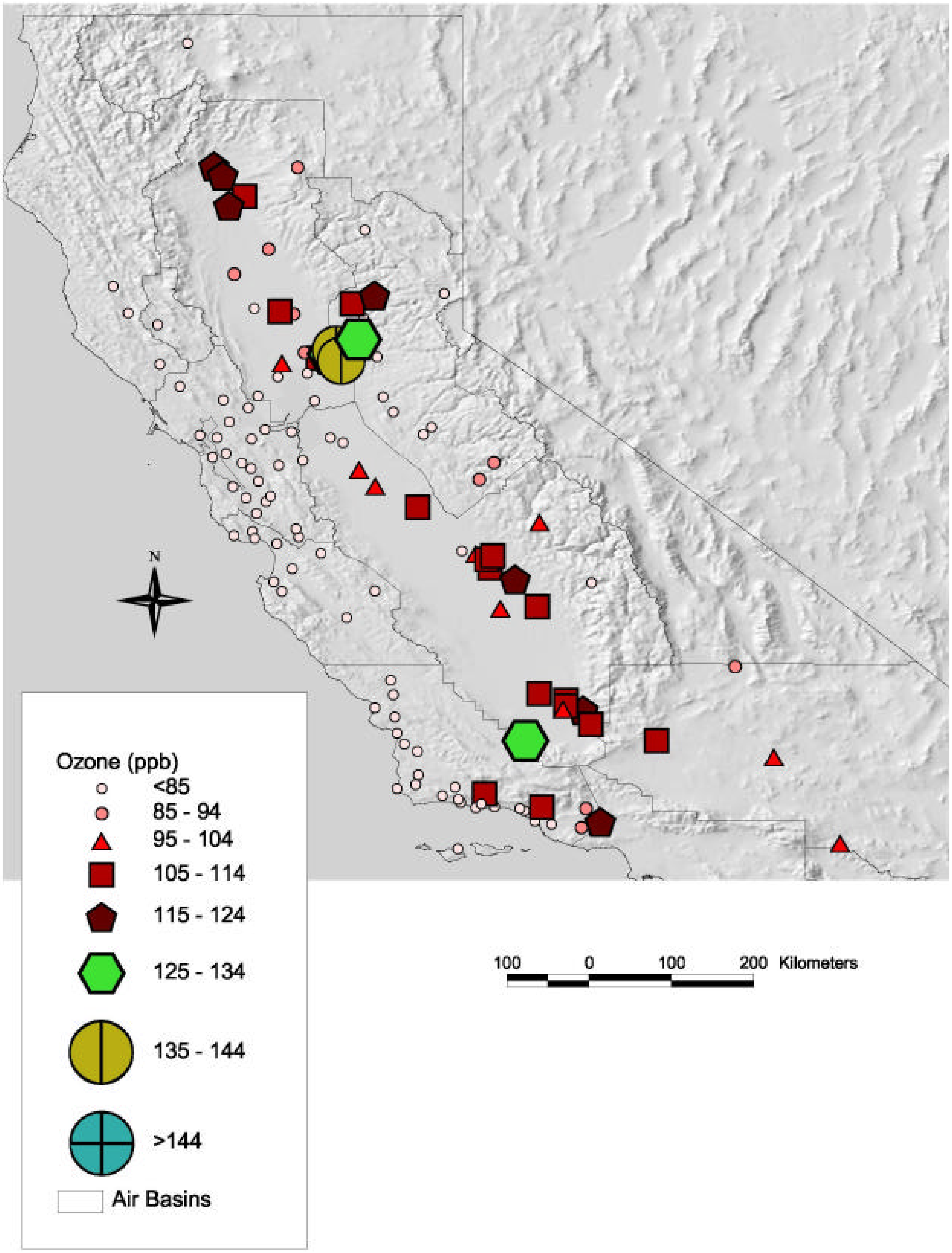


Figure 1.3-6. Maximum 1hr ozone for 126 monitoring stations on 8/14/98, a Cluster 3 Day.

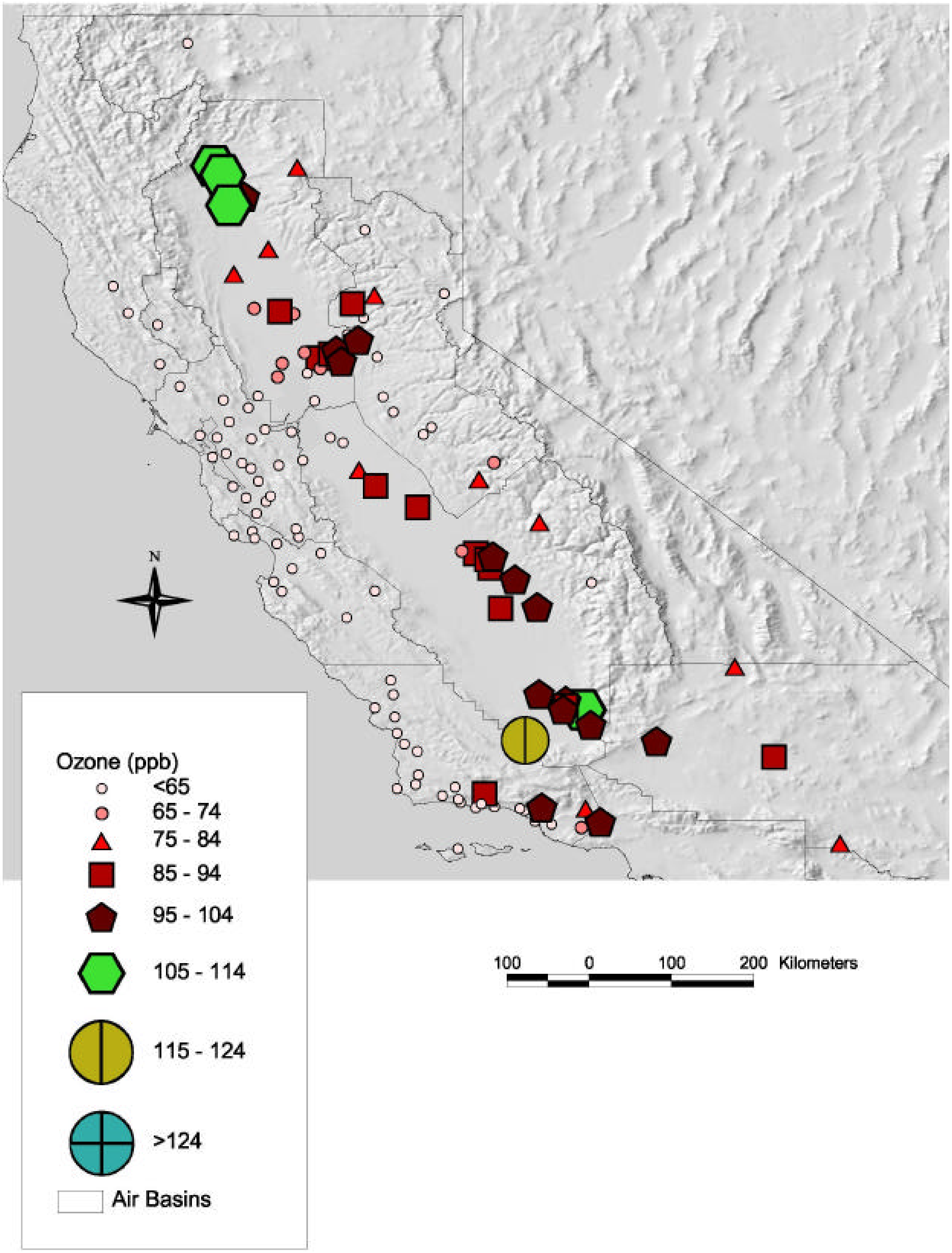


Figure 1.3-7. Maximum 8hr ozone for 126 monitoring stations on 8/14/98, a Cluster 3 Day.

The identification of meteorological scenarios is an on-going task of the CCOS Meteorological Working Group. Ozone season days, May 1 – October 31, have been classified for three recent seasons, 1996-1998, using two complementary approaches. This effort is a top-down approach using inspection of 500-mb weather maps to establish gross features and to classify all 552 subject days into eight categories, including 2-4 subcategories for six of the eight scenarios. These scenarios are presented here in the approximate order of decreasing ozone impact:

1. Western U.S. High – Upper-level high pressure center located over the Western U.S.

2. Eastern Pacific High – Upper-level high pressure center off the Western U.S. coast

3. Monsoonal Flow – Upper-level high pressure center in the south-western U.S. or in northern Mexico such that southerly flow brings moisture north

4. Zonal Flow – West-to-East

5. Pre-Frontal – Front approaching from northwest brings southwesterly flow

6. Trough Passage – Upper-level trough moves through California, usually ventilating Central California.

7. Continental High – Northerly wind with no marine component, more typical in winter

8. El Nino Cut-off Low – A special class for 1997 where a cut-off low sat just of the southern California coast for several days.

The Western U.S. high accounts for proportionately the greatest number of exceedances. As shown in Table 2.5-3, 97% of days with highs centered over southern California have 8-hour exceedances in the Central San Joaquin Valley, where the frequency of exceedances on all 1996-98 ozone season days is 42%. The Western U.S. High contributes to stagnation conditions throughout central California by fostering an off-shore gradient which weakens (and in some cases even reverses) the usual sea breeze. Compared to a more vigorous sea breeze scenario like the Eastern Pacific High, this tends to keep pollutants longer within respective source regions, although some transport can still occur with the delayed and/or weakened sea breeze. The SFBA has 8-hour exceedances on 29% of days when the Western U.S. High is centered over the Pacific Northwest, while the frequency of SFBA 8-hour exceedances on all 1996-98 ozone season days is only about 4%. This scenario also provides abundant sunlight and the greatest subsidence inversion to reduce mixing heights and trap pollutants vertically all over central California. Monsoonal flow can have both mitigating and exacerbating impacts on SJV air quality. Some monsoonal days are identified (e.g., 9/3/98), where SJV ozone is lower relative to the rest of Central California, but on other days, the southerly monsoonal flow can weaken the SJV exit flow through Tehachapi Pass. Zonal flow tends to increase synoptic forcing, and less ozone impact is seen in the northern portion of the study area, but the topography surrounding the SJV helps decouple the valley from the upper level winds, and many exceedances are observed in SJV during zonal flow. The last four scenarios all help ventilate the Central Valley. There were no 1-hour exceedances during any of the 142 out of 552 days studied (26%), although some 8-

hour exceedances are observed in the SJV and the Mountain Counties even with a trough passage.

While these results are conceptually helpful, interpretation and application of the top-down approach is limited due to the large scale of the eight classes that does not allow for adequate consideration of day-to-day atmospheric variability and of smaller mesoscale effects. Additionally, during the Western U.S. High, when synoptic forcing over central California is weakest, ozone concentrations are greatest, and mesoscale features which re-distribute ozone and precursors become most important. Subtle synoptic differences, fostering the formation and/or amplification of these features, are difficult to identify and classify.

1.3.4 Episode Forecasting and Selection

The broad goal of the meteorological working group is to develop protocols for forecasting and selecting episodes of interest for intensive study. The group has undertaken four efforts, each with a task leader, to accomplish this goal. These efforts will be described and the protocols documented in the operational plan.

a. <u>Define regional mesoscale flow features</u> – Create a document with mesoscale flow features identified. Define the air quality impact of each feature. Develop operational definitions to define the presence or absence of each feature. Evaluate locations of existing and proposed stations to adequately define each feature. These features include:

- Sea breeze
- Marine air intrusion
- Coastal Windflow – off-shore flow, north or south along coast
- Marine fog and stratus
- San Joaquin Valley/Sacramento Valley Bifurcation Zone – location and relative proportions of air moving north, east, and south.
- Pacheco Anti-Cyclone – possible impact on SJV to San Louis Obispo area transport.
- Fresno Eddy – degree to which pollutants are trapped and re-entrained in central SJV with the damming of air against the Tehachapi mountains and subsequent recirculation.
- Schultz Eddy – impacts of transport to northern mountain counties and upper SV
- Redding Eddy – Discuss any evidence for and or possible importance to air quality in the Redding area.
- Upper/Lower SV Convergence zone
- Upper/Lower SJV Convergence zone
- Upslope/Downslope
- Up-valley/Down-valley
- Compensation Flow/Re-entrainment

b. <u>Investigate the use of forecast models</u> – Evaluate the use of daily runs of mesoscale models for local forecasts. This is currently done in other areas. For example, the University of Utah performs daily forecast runs for Salt Lake City and the surrounding area. The Naval Post-Graduate School is involved in this activity in California and CCOS may coordinate these efforts.

c. Establish website tool for forecast – Create a web site with near real-time display of selected meteorological and air quality data. This would include consolidated information from NWS, ARB, military sites, local districts and other sources.

d. Develop forecast team protocol – Define the composition and operations of the forecast team. Develop criteria for go/no-go decision and selection of episodes. This will likely be modeled after previous successful forecast team efforts like the SARMAP 1990 and SCOS97 effort.

1.4 Overview of CCOS Field Measurements

Data requirements for CCOS are determined by the need to drive and evaluate the performance of modeling systems, which include three components. A meteorological model provides winds fields, vertical profiles of temperature and humidity, and other physical parameters in a gridded structure. Emissions inventory and supporting models provide gridded emissions for anthropogenic area and point sources and natural emissions. An air quality model simulates the chemical and physical processes involved in the formation and accumulation of ozone. In evaluating modeling system performance, the primary concern is replicating the physical and chemical processes associated with actual ozone episodes. This necessitates the collection of suitable meteorological, emissions, and air quality data that pertain to these episodes. The data requirements of CCOS are also driven by a need for complementary, independent and corroborative data analysis so that modeling results can be compared to current conceptual understanding of the phenomena replicated by the model. Data requirements for CCOS are summarized in Section 1.5 (details in Section 3).

The CCOS field measurement program will be conducted during a four-month period from 6/1/00 to 9/30/00. A network of upper-air meteorological monitoring stations will supplement the existing routine meteorological and air quality monitoring network in order to identify and characterize meteorological scenarios that are conducive to ozone formation during the ozone season. Supplemental air quality measurements will be made during a three-month period from 6/15/00 to 9/15/00 (***study period***), which corresponds to the majority of elevated ozone levels observed in northern and central California during previous years. Continuous surface and upper-air meteorological measurements and surface air quality measurements of O_3 NO, NOx or NOy[6] will be made hourly throughout the study period in order to provide sufficient input data to model any day during the study period. These measurements are made in order to assess the representativeness of the episode days, to provide information on the meteorology and air quality conditions on days leading up to the episodes, and to assess the meteorological regimes and transport patterns which lead to ozone episodes.

Additional continuous surface air quality measurements will be made at several sites during a shorter two-month study period from 7/6/00 to 9/2/00 (***primary study period)***. These measurements include nitrogen dioxide (NO_2), peroxyacetylnitrate (PAN) and other peroxyacylnitrates (PAcN), particulate nitrate (NO_3^-), formaldehyde (HCHO), and speciated

[6] Reactive oxidized nitrogen (NOy) include nitric oxide (NO), nitrogen dioxide (NO2), nitrous acid (HONO), peroxynitric acid (HNO4), nitrate radical (NO3), nitrate aerosol (NO3-), dinitrogen pentoxide (N2O5), nitric acid (HNO3), peroxyacetylnitrate (PAN) and other PAN analogues, and organic nitrates (ORNI).

volatile organic compounds. These measurements allow detailed examination of the diurnal, day-to-day, and day-of-the-week variations in carbon and nitrogen chemistry at transport corridors and at locations downwind of the San Francisco Bay Area, Sacramento, Fresno, and Bakersfield where ozone formation may be either VOC- or NOx-limited depending upon time of day and pattern of pollutant transport. These data support operational and diagnostic model evaluations, evaluations of emission inventories, and corroborative observation-based data analyses.

Additional data will be collected during ozone episodes (***intensive operational periods***, ***IOP***) to better understand the dynamics and chemistry of the formation of high ozone concentrations. The budget for CCOS allows for up to 15 days total for episodic measurements. With an average episode of three to four days, four to five episodes are likely. These measurements include instrumented aircraft, speciated VOC, and radiosonde measurements, which are labor intensive and require costly expendables or laboratory analyses. IOPs will be forecasted during periods that correspond to categories of meteorological conditions called scenarios, which are associated with ozone episodes and ozone transport in northern and central California. These intensive measurements will be made on days leading up to and during ozone episodes and during specific ozone transport scenarios. The additional measurements are needed for operational and diagnostic model evaluation, to improve our conceptual understanding of the causes of ozone episodes in the study region and the contribution of transport to exceedances of federal and state ozone standards in downwind areas.

1.4.1 Surface Meteorological and Air Quality Measurements

The existing meteorological network in central California is extensive, but uncoordinated among the different agencies. Surface meteorological monitoring networks includes those operated by the Air Resources Board (ARB), the Bay Area Air Quality Management District (BAAQMD), the National Oceanic and Atmospheric Administration (NOAA), the California Irrigation Management Information Service (CIMIS), Interagency Monitoring of Protected Visual Environments (IMPROVE), the National Weather Service (NWS), Pacific Gas and Electric Company (PG&E), the U.S. Coast Guard, Remote Automated Weather Stations (RAWS) for fire fighting, and a few miscellaneous monitors. Wind speed and direction, temperature, and relative humidity are the most common measurements. The network of surface pressure and solar radiation measurements is also extensive. Three sites measure ultraviolet radiation in the Sacramento Valley, in the San Joaquin Valley, and along the south coast in Santa Barbara County.

The California Air Resources Board and local air pollution control districts currently operate 185 air quality monitoring stations throughout northern and central California. Of the active sites, 130 measure ozone and 76 measure NOx. Carbon monoxide and hydrocarbons are measured at 57 and 11 sites, respectively. Data from these sites are routinely acquired and archived by the ARB and Districts. This extensive surface air quality monitoring network provides a substantial database for setting initial condition for the model, and for operational evaluation of model outputs.

The existing meteorological network will be augmented with the CCOS supplemental sites described below. Ten meter meteorological towers at each of newly established CCOS supplemental sites will be equipped with low threshold (~0.3 m/s) wind sensors and high sensitivity relative humidity sensors. Supplemental air quality measurement are required at several existing monitoring sites to increase the extent of chemical speciation and in key areas of the modeling domain where routine monitoring stations do not currently exist. Measurements of documented quality and adequate sensitivity are needed along the western boundary of the modeling domain to adequately characterize the temporal and spatial distributions of ambient background levels of ozone precursors because boundary conditions can significantly affected model outputs. Background sites intend to measure concentrations that are not influenced by northern and central California emissions. Interbasin transport sites are intended to evaluate concentrations along established or potential transport pathways between basins, including the Bay Area, the North Central Coast Air Basin, the Sacramento Valley, the San Joaquin Valley, Mountain counties, the South Central Coast Air Basin, and the Mojave desert. Intrabasin gradient sites are located in non-urban areas between routine network sites. They are intended to evaluate the extent to which one urban area affects ozone concentrations in another urban area, as well as the extent to which urban contributions arrive at suburban and rural locations. The CCOS field measurement program consists of four categories of supplemental measurement sites with increasing levels of chemical speciation and time resolution – Type 0, 1, and 2 “supplemental” (S) sites and “research” (R) sites. Table 1.4-1 lists the measurements (described in Appendix A) to be made at each of type of supplemental monitoring sites along averaging times and operating schedules.

Type 0 supplemental monitoring sites (S0) are intended to fill in key areas of the modeling domain where ozone and nitrogen oxides are not currently measured. Proposed sites include McKittrick and Kettleman City (both along the western side of the San Joaquin Valley), Shasta (downwind of Redding), and Carizo Plain (along transport route between San Luis Obispo and the southern San Joaquin Valley). In addition NO/NOy analyzers will be added at several existing monitoring sites that currently measure only ozone. Three of these sites are located along pollutant transport routes (Vacaville, San Martin, and Walnut Grove Tower at two elevations). Yosemite (Turtleback Dome) is proposed in order to monitor NO/NOy at a site where formation of ozone is expected to be always NOx limited.

Type 1 supplemental monitoring sites (S1) are intended to establish boundary and initial conditions for input into air quality models. These sites are needed at the upwind boundaries of the modeling domain, in the urban center (initial conditions) and at downwind locations (boundary conditions). With the exception of NOy measurements, S1 sites are equivalent to Photochemical Assessment Monitoring Stations (PAMS) sites. Measurements of speciated volatile organic compounds (VOC) made under CCOS (four 3-hour samples on 15 IOP days) supplement the 11 existing PAMS sites in the study area (four in Sacramento, four in Fresno, and three in Bakersfield). The ozone episodic samples that will be collected under PAMS will coincide with the CCOS IOP days. S1 sites are proposed for Bodega Head and along the south central coast north of Morro Bay to obtain background data near the western boundary of the CCOS modeling domain. Sutter Buttes and Turlock provide characterization of ambient air transported into the upper Sacramento Valley and into the northern San Joaquin Valley, respectively, as a function of the nature of the flow bifurcation downwind of the San Francisco Bay Area. Measurements at Anderson (located south of Redding) are designed to determine whether ozone precursors immediately upwind of Redding are largely transported or are

Table 1.4-1
CCOS Supplemental Surface Measurements

Observable and Method	Period	Avg Time	Type of Sites
Meteorology and Radiation			
Meteorology (WS,WD, T and RH) at 10 m	6/15/00 to 9/15/00	5-minute	S0, S1, S2 and R
Radiation (J_{NO2} and J_{O1D})	6/15/00 to 9/15/00	5-minute	R
Oxidants			
Ozone (ultraviolet absorption monitor)	6/15/00 to 9/15/00	5-minute	S0, S1, S2 and R
H_2O_2 (TDLAS)	15 IOP days	10-minute	R (1)
Nitrogen Species			
NO, NOx (chemiluminescent monitor)	6/15/00 to 9/15/00	5-minute	S2, R
NO, NOy (high sensitivity chemiluminescent monitor with external converter)	6/15/00 to 9/15/00	5-minute	S0, S1
NOy, NOy-HNO_3 (high sensitivity chemiluminescent monitor with dual converters w/ & w/o NaCl impregnated fiber denuder)	6/15/00 to 9/15/00	10-minute	S2, R
NO_2, PAcNs (GC - Luminol)	7/2/00 to 9/2/00	30-minute	S2, R
NO^{-} (flash vaporization)	7/2/00 to 9/2/00	10-minute	R
NO_2, HNO_3 (TDLAS)	15 IOP days	10-minute	R (1)
Carbon Species			
CO, CO2, CH4, C_2-C_{12} hydrocarbons (canister/GC-FID)	15 IOP days	4 x 3-hr	S1, S2, R
C_1-C_7 carbonyls(DNPH-HPLC/UV)	15 IOP days	4 x 3-hr	S1, S2, R
HCHO (dihydrolutinine derivative/fluorescent detection)	7/2/00 to 9/2/00	10-minute	S2, R
C_8-C_{20} hydrocarbons (Tenax GC-FID, MSD)	15 IOP days	4 x 3-hr	R
VOC (Automated-GC/ion trap mass spectrometer)	7/2/00 to 9/2/00	hourly	R
HCHO (TDLAS)	15 IOP days	10-minute	R (1)
Hydroxy carbonyls	15 IOP days	hourly,	R(2)
CO (nondispersive infrared)	6/15/00 to 9/15/00	5-minute	R
CO_2 (nondispersive infrared)	6/15/00 to 9/15/00	5-minute	R
PM/Visibility			
PM2.5 light absorption (aethalometer)	6/15/00 to 9/15/00	5-minute	R
PM2.5 light scattering (portable nephelometer)	6/15/00 to 9/15/00	5-minute	R

(1) At the Fresno research site only.
(2) At the Sacramento research site only.

attributable to local sources. Similar transport issues will be addressed by measurements in the foothill communities near Grass Valley and San Andreas. Type S1 measurements are also proposed for the CRPAQS Anchor site at Angiola. The Bay Area AQMD will operate the existing San Jose and San Leandro monitoring sites as S1 sites during CCOS.

Type 2 supplemental monitoring sites (S2) are located at the interbasin transport and intrabasin gradient sites, and near the downwind edge of the urban center where ozone formation may either be VOC or NOx limited depending upon time of day and pattern of pollutant transport. S2 sites also provide data for initial conditions and operation evaluations and some diagnostic evaluation of model outputs. Measurements at S2 sites include those at S1 sites plus continuous NOy* (NOy minus nitric acid), nitrogen dioxide (NO2), peroxyacetylnitrate (PAN) and formaldehyde (HCHO). The measurements allow more detailed assessments of VOC- and NOx-limitation by observation-driven methods during the entire two-month primary study period. S2 sites are proposed along the three main passes connecting the Bay Area and the Central Valley (Bethel Island, Altamont Pass, and Pacheco Pass. S2 measurements are also proposed downwind of Fresno at the Mouth of the Kings River and downwind of Bakersfield at Edison. One additional Type S2 site will be located east of Sacramento.

Research sites (R) have the same site requirements as S2 sites. The sites are intended to measure a representative urban mix of pollutants, and must be carefully selected to minimize the potential influence of local emission sources. As with S2 sites, research sites are located where ozone formation may either be VOC or NOx limited depending upon time of day and pattern of pollutant transport. Research site are intended to provide the maximum extent of high-quality, time-resolved chemical and other aerometric data for rigorous diagnostic evaluation of air quality model simulations and emission inventory estimates. VOC speciation will be obtained at research sites hourly rather than four 3-hour samples at S1 and S2 sites. Other continuous measurements carbon monoxide, carbon dioxide, photolytic rate parameters, light adsorption and scattering. Data for these measurements will be collected during the primary study period of two months. Other measurements that will be made during ozone episodes include NO_2, HNO_3, HCHO, and hydrogen peroxide (H_2O_2) by tunable diode laser absorption spectroscopy (TDLAS), C_8 to C_{18} hydrocarbons and hydroxy carbonyl compounds. Research sites are proposed downwind of Sacramento and Fresno, and near Dublin between Oakland and Livermore.

1.4.2 Aloft Meteorology and Air Quality Measurements

Table 1.4-2 describes the upper air sites, their measurements and operators. Radar profilers, doppler sodars, and RASS are used at most sites because they acquire hourly average wind speed, wind direction, and temperature by remote sensing without constant operator intervention. Sodars are collocated with profilers at several locations because they provide greater vertical resolution in the first 100 m agl. Several radar profilers are being installed to acquire a multi-year database, and one of the important functions of the CCOS/CRPAQS supplements to this network is to relate these relatively sparse measurements to the detailed meteorological patterns determined during CCOS. The ARB operates two profilers (with RASS) in the San Joaquin Valley, and the San Joaquin Valley Unified APCD and Sacramento Metropolitan AQMD operate one profiler/RASS each as part of their PAMS monitoring

Table 1.4-2
CCOS Upper-Air Meteorological Measurements

ID	Name	Purpose	Operator[a]	Contractor	Radar[b]	RASS[b]	Sodar[b,c]	Sonde[b,d]
ABK	Arbuckle	Intrabasin Transport	CCOS/ CRPAQS	ETL/NOAA	SC	SC		
ABU	N. of Auburn, S. of Grass Valley	Upslope/Downslope Flow, Downwind of Major Source Area	CCOS	ETL/NOAA	SC	SC		
ACP	Angel's Camp	Upslope/Downslope Flow	CCOS/ CRPAQS	ETL/NOAA			SC	
ANGI	Angiola	Intrabasin Transport, Vertical Mixing,	CCOS/ CRPAQS	ETL/NOAA	AC	AC	SC	
CRG	Corning	Northern Valley Barrier and Convergence Cone	CCOS/ CRPAQS	ETL/NOAA	SC	SC		
EDI	Edison	Interbasin Transport through Tehachapi Pass	ARB		AC	AC		
EDW	Edwards AFB	Interbasin Transport through Tehachapi Pass, Desert Mixed Layer, Synoptic Conditons	EAF					AS
FAT	Fresno Air Terminal	Intrabasin Transport, Fresno Eddy, Major Soure Area	CCOS/ CRPAQS	ETL/NOAA	SC	SC	SC	
FSF	Fresno-First Street	Urban Heat Island, Intrabasin Transport, Synoptic Conditons. Major Source Area	CCOS/ CRPAQS	TBD				SE
HUR	Huron	Intrabasin Transport, SJV Nocturnal Jet	CRPAQS		AC	AC		
LGR	Lagrange	Upslope/Downslope Flow, Mariposa River Valley	CRPAQS	ETL/NOAA	SC	SC	SC	
LHL	Lost Hills	Intra&Interbasin Transport across Carizo Plain	ARB		AC	AC		
LIV	Livingston	Intrabasin Transport, mid-SJV Valley Axis Flow	CCOS/ CRPAQS		AC	AC	SC	
MJD	Mojave Desert	Interbasin Transport, Downwind of southern SJV	CRPAQS		AC	AC		
MKR	Mouth Kings	Upslope/Downslope Flow	CRPAQS/ CCOS		AC	AC		
MON	Monterey	Onshore/Offshore Transport	USNPGS		AC	AC		
NTD	Point Mugu USN	Onshore/Offshore Transport, Synoptic Conditions	USN					AS
OAK	Oakland airport	Onshore/Offshore Transport, Synoptic Conditions	NWS					AS
RIC	Richmond	Onshore/Offshore Transport	BAAQMD/ CCOS	ETL/NOAA	SC	SC	AC	
SAC	Sacramento	Intrabasin Transport	SMAPCD		AC	AC		SE
SNA	Santa Nella, E of I-5 toward Los Banos	Interbasin Transport through Pacheco Pass	CCOS		AC	AC		
TRA	Travis AFB	Interbasin Transport between Valley and Bay Area	TAF		AC			
TRC	Tracy, W of Tracy, S of I-205, W of I-580	Interbasin Transport through Altamont Pass	CCOS	STI	SC	SC		
VBG	Vandenberg AFB	Onshore/Offshore Transport, Synoptic Conditions	VAF		AC			AS
VIS	Visalia	Intrabasin Transport	SJVUAPCD		AC	AC		
	Pt. Reyes	Onshore/Offshore Transport	CCOS	STI	SC	SC		
LVR	Livermore	Intrabasin Transport from Oakland to Livermore	CCOS	STI	SC	SC		
	San Martin	Interbasin Transport from Bay Area to North Central Coast	CCOS	STI	SC	SC		
CAR	Carizo Plain	Interbasin Transport from San Joaquin Valley to South Central Coast Air Basin	CCOS	ARL/NOAA	SC	SC	SC	
PLE	Plesant Grove	Interbasin Transport from Sacramento to Upper Sacramento Valley	CCOS	ETL/NOAA	SC	SC		

[a]CCOS=Central California Ozone Study (this study)' ARB=Air Resoures Board, BAAQMD=Bay Area Air Quality Management District; USNPGS=U.S. Navy Post Graduate School; SJVUAPCD=SJV Unified Air Pollution Control District, NWS=National Weather Service; SMAQMD=Sacramento Metropolitan Air Quality Management District, CRPAQS=California Regional PM10/PM2.5 Air Quality Study; VAF=Vandenberg Air Force Base, TAF=Travis Air Force Base, EAF=Edwards Air Force Base, USN=U.S. Navy.

[b]AC=Annual continuous measurements; AS=Annual sporadic measurements, SC=Summer continuous, 6/1/2000-9/30/2000; SE=Summer episodic measurements on forecasted days.

[c]Summer campaign sodars added at some sites as part of CRPAQS/CCOS except at RIC.

[d]Balloon launch on episode days. Frequency should be 4-8 times per day but include 0700 and 1900 PST.

program. Military facilities with operational profilers include Travis AFB, Vandenberg AFB, and the Naval Post Graduate School in Monterey. As part of CRPAQS, NOAA will upgrade existing equipment, as required, at these facilities, and coordinate data collection to ensure compatibility with the CRPAQS/CCOS upper-air database. Because these profilers are operated by different entities, equivalent methods of data evaluation and reporting need to be established among these entities prior to CCOS field study. Six profiles/RASS will be installed and operational during summer 2000 as part of the CRPAQS. In addition, nine profilers/RASS and 5 sodars will be installed for the CCOS summer 2000 field study.

Another radar/RASS profiler will be located in the vicinity of the power plant stacks selected for study to ensure that the local 3D winds are well defined for accurate model simulation during the crucial early stages of plume dispersion. Measurements are planned for the power plants at Moss Landing and at Pittsburgh and the radar/RASS profiler will be moved as necessary. Radiosondes are needed to determine changes in relative humidity and to quantify conditions at elevations above ~2000 m agl. They are also the only practical means of acquiring upper air measurements in cities where the noise and siting requirements of remote sensing devices make them difficult to operate. Radiosondes are routinely launched through the year at 0400 and 1600 PST from Oakland, with additional launches at Vandenberg, Edwards, and Pt. Mugu according to military mission requirements. None of these locations are within the Central Valley, so these will be supplemented by launches at Sacramento and in the southern San Joaquin Valley on 15 episodic days during summer with six radiosondes (with ozonesonde) releases per day. The 490 MHz RWP will be placed in the Fresno area to provide higher vertical soundings in the central San Joaquin Valley.

In addition to ozonesondes mentioned in the previous section, aloft air quality measurements are available from fixed platforms that are part of the routine monitoring network (e.g., Walnut Grove radio tower and Sutter Buttes). CCOS will add NOy measurements at Walnut Grove and Sutter Buttes to provide additional information on oxidants available as carry-over to mix-down on the following day.

Four aircraft are proposed for the CCOS field study. Instrumented aircraft will be used to measure the three dimensional distribution of ozone, ozone precursors, and meteorological variables. For CCOS, aircraft data have five specific uses:

- Aloft boundary and initial conditions – direct input to model.
- Definition of temporal and spatial ozone patterns in layers aloft – model evaluation.
- Direct measurement of mixing depth during spirals – model evaluation and many corroborative studies.
- Flux plane estimation of transport - model evaluation and corroborative transport assessment.
- Reconciliation of aloft data with the conceptual model.

Three small air quality aircraft are needed to document the vertical and horizontal gradients of ozone, NOx, ROG, temperature, and humidity in the study region. One aircraft is needed for the Bay Area, a second aircraft for the northern boundary, Sacramento Valley and northern Sierra Nevada, and a third aircraft for the San Joaquin Valley and the central and southern Sierra Nevada. Onboard air quality instruments should have high sensitivity and fast response (e.g., modified TEI 42S for NO and NOy). The small aircraft will make one flight in the early morning (0500 to 0900 PDT) to document the morning precursors and the carryover from the day before and a second flight in mid-afternoon (1300 to 1700 PDT) to document the resulting ozone distribution. An occasional third flight might be considered during the night to characterize the nocturnal transport regime and pollutant layers. Flights last between three to four hours and may consist of a series of spirals (over fixed points on the ground) and traverses (at constant altitude from one point to another) throughout the mixed layer. One of these aircraft will also participate in characterizing flux-planes. All aircraft will have the capability to measure wind direction and speeds.

A larger multi-engine aircraft will be used to document the horizontal and vertical gradients along the offshore boundaries of the modeling domain, Bay Area and the North Central Coast. This plane will carry the same instrumentation as the smaller planes. This long-range aircraft will make two flights per day, one in the early morning and one in mid-afternoon. The flights will take about four hours and will likely consist of a series of dolphin patterns (slow climbs and descents along the flight path) and traverses. During one leg of the morning flight of the first day of an IOP, this aircraft will measure the concentrations at the western, overwater boundary of the study area. On the return leg, the aircraft will document the concentrations and fluxes across the shoreline. VOC samples are collected during constant-altitude traverses for the overwater boundary and during several spirals for the shoreline legs. Boundary measurements will be made during both non-episode and episode days. This plane will also participate in flux plane measurements.

Hydrocarbon samples are collected in stainless steel canisters and carbonyl samples are collected in Tedlar bags and transferred to dinitrophenyl hydrazine impregnated cartridges on the ground at the conclusion of the flight. Hydrocarbon samples are subsequently analyzed in the laboratory by gas chromatography with flame ionization detection and carbonyl samples are analyzed in the laboratory by HPLC with UV detection. The budget allows for collection and analysis of three or four sets of hydrocarbon and carbonyl samples per flight. The specific flight plans will be developed over the next several months for the four aircraft under different meteorological scenarios. The above general description of flight patterns and objectives of each flight will be specified in the operational program plan.

Helicopter based measurements of power plant plume will be used to evaluate the plume-in-grid (PiG) parameterizations used in air quality models. With PiG parameterizations plume emissions are simulated in a Lagrangian reference frame superimposed on the Eulerian reference frame of the host grid model. Ozone formation rates in the plume of an elevated point source will be different from the ambient air because of their very different VOC/NOx ratios. CCOS measurements of ozone, VOC and nitrogenous compounds in plumes and in the surrounding air will be compared with the simulations of models using the PiG approach. The plume study is described in Addendix D.

In addition to the instrumented aircraft, both airborne and ground-based lidars, and network of ozonesondes have been used in previous studies to obtain vertical ozone measurements. The CCOS Technical Committee discussed the merits of these alternative approaches and reached the consensus that a small fleet of instrumented aircraft would provide the most cost-effective approach given the tradeoffs between temporal and spatial information and requirements for pollutant flux and plume measurements. The rationale for the Committee's recommendation is explained further in Section 4.8. The CCOS field measurement program is described in detail in Section 4.

1.4.3 Complementary Measurement Programs

The current study emphasizes collection of data that are needed to model transport between air basins. Because a Photochemical Assessment Monitoring Station (PAMS) network does not exist in the Bay Area, the density of air quality measurements (e.g., NO/NOy and VOC) in the Bay Area is lower than is needed to reliably understand and simulate the conditions that result in days exceeding the ozone standard in the Bay Area alone. The Bay Area AQMD will sponsor additional measurements during CCOS to obtain the information needed to develop a Bay Area specific plan.

The supplemental Bay Area measurements are primarily designed to increase the understanding of high ozone in the Livermore Valley, where the Bay Area's highest ozone levels and most frequent exceedances of the standards occur. For this purpose, four types of measurements are proposed: 1) Monitoring of pollutant levels aloft on selected episode days with instrumented aircraft flights within and upwind of the Livermore Valley; 2) surface monitoring of ozone and precursor gases in the gaps through which air enters and exits the Livermore Valley; 3) continuous aloft measurements of wind and temperature, using Doppler acoustic sounders and radar profilers, above the Livermore Valley and its entrance and exit gaps; and 4) remote sensing of on-road vehicle exhaust to verify that the emissions that are input to the photochemical model are accurate.

The CCOS field measurement program will be conducted in conjunction with the California Regional PM_{10}/$PM_{2.5}$ Air Quality Study (CRPAQS). The CRPAQS includes air quality and meteorological field measurements, emissions characterization, data analysis and air quality modeling. The CRPAQS field study will consist of a long-term campaign from 12/1/99 through 1/31/01, a winter intensive study within the period of 11/15/00 through 1/31/01, and a fall intensive study within the period of 9/1/00 through 10/31/00. Several experiments will be conducted during the summer period of 7/1/00 through 8/31/00. These include chemical characterization of $PM_{2.5}$ at the Fresno site to estimate the fraction of fine particles that is attributable to secondary organic aerosol and source contributions of directly-emitted fine particles. Other experiments will examine the timing and intensity of light extinction in the San Joaquin Valley and the Mohave Desert. The baseline measurements for CRPAQS, which will begin in December 1999 and continue to the end of the study, are incorporated and leveraged into the CCOS field program. These include six upper-air meteorological measurement sites within the CCOS domain. Opportunities for cost sharing also exist for purchases of instruments that are needed for both CCOS and the CRPAQS winter intensive study (e.g., NO_2, PAN, and NOy and continuous particulate nitrate). CCOS will also benefit from measurements that are available throughout the study region from existing federal, state, local, and private air quality and meteorological monitoring programs.

1.4.4 Consideration of Measurement Alternatives

An investigation of the various processes that are important for ozone formation would require extensive measurements for each process. This detailed investigation for each process goes beyond the resources of CCOS. Although this is a potential limitation, the corroborative analysis of other detailed process studies can be used to evaluate the conceptual model and identify data needs that can be met by future studies.

During the California Ozone Deposition Experiment (CODE) in 1991, aircraft and tower-based flux measurements were taken over different types of San Joaquin Valley crops, irrigated and non-irrigated fields, and over dry grass. Estimates of ozone deposition velocities are 0.7-1.0 cm/s (Pederson et al. 1995). Order of magnitude calculations by Pun et al. show that dry deposition can be a few percent (~3-5%) of the total ozone budget in the San Joaquin Valley. However, modeling studies (Glen Cass, personal communication) have shown that dry deposition can play a more significant role in the budget of an important ozone precursor, NO_2. Three alternative deposition studies were considered. Two are tower-based and could take advantage of the 100-m tower at Angiola planned for CRPAQS. The third is an aircraft flux measurement and could be used for a variety of different terrain types. The consensus view of the CCOS Technical Committee was that a proper study of atmospheric deposition would require far more funds than available within CCOS. Rather than dilute the CCOS effort, the Committee recommended that separate funding be sought for a comprehensive deposition study in the year 2001.

Other tests of atmospheric chemistry such as the measurements made at the University of Michigan Biological Research Station (UMBS) near Pellston, Michigan, under the Program for Research on Oxidants: PHotochemistry, Emissions and Transport (PROPHET) (Carroll et al., 1998 http://aoss.engin.umich.edu/PROPHET/) should be analyzed as part of the corroborative analysis. Data were collected in summer 1997 and 1998, and a third field study is planned for 2000. The data set includes: continuous measurements of meteorological parameters, ultraviolet radiation, ozone, CO, peroxyacetyl nitrate (PAN), peroxypropionyl nitrate (PPN), peroxymethacrylic nitric anhydride nitrate (MPAN); simultaneous measurements of nitrogenous species, NOx, NOy, HONO, HNO3 and organic nitrates; measurements of volatile organic compounds and organic peroxy radicals (ROx); HO and HO2 radicals; peroxides, and the physical properties and chemical composition of aerosol (Carroll et al., 1998). The PROPHET study provides a very complete data set from one site that can be used to develop and evaluate the chemical mechanisms used air quality models with a level of detail that will not be obtained under CCOS.

1.5 Applications of CCOS Data for Evaluation of Air Quality Modeling Systems

Air quality modeling systems are composed of three major components: 1) the meteorological model, 2) the emissions inventory and 3) the air quality model. Each of these components must be evaluated on its performance in simulating the physical and chemical processes associated with actual ozone episodes. An overview of the application of CCOS data to this evaluation is given below. One of the main objectives of CCOS is to evaluate the performance of air quality modeling systems. The CCOS data will be used to assess the performance in operational and diagnostic evaluations. Operational evaluations involve comparing model simulations with ambient measurements. Diagnostic evaluations assess a model's representation of the physical and chemical processes to determine if the model estimates the correct ozone concentrations for the correct reasons.

1.5.1 Meteorological Models

An air quality model requires the meteorological fields that drive the transport and dispersion of atmospheric pollutants. The meteorological situation in central California is difficult to model due to its complex topography. The larger scale meteorological flows in northern and central California are channeled by the Sacramento and San Joaquin Valley. On a smaller scale the concentrations of air pollutants are affected by land-sea breezes, urban circulations, local flows (slope and drainage), and diurnal variation of thermal stability and wind shear. The mixing depth for both convective and stable conditions is very important to model but the treatment of the atmospheric boundary layer (ABL) is difficult to characterize for the stable and stagnant conditions associated with episodes of high ozone. The depth of the stable atmospheric boundary layer (ABL) may be of the order of 100 m, and a number of local effects such as urban land use, vegetation, soil properties, and small-scale topographic features, can significantly influence ABL characteristics. All of these factors contribute to a challenging meteorological situation for the models.

The meteorological models will use surface network measurements of wind speed and direction, temperature, humidity, pressure, solar radiation, and precipitation available from routine aloft network measurements. This routine data set will be augmented by the CCOS data that will include: additional surface sites for the routine measurements listed above, a number of airborne and remote sensing upper-air measurements, turbulence by sonic anemometer, actinic flux for photolysis of key species, and soil moisture for key land use.

These data will be used as input to the Mesoscale Meteorological Model, version 5 (MM5) and it will be run in both fully predictive and data assimilation modes. Four-Dimensional Data Assimilation (4DDA) involves the use of observations to "nudge" the prognostic calculations of a meteorological model back to the observed meteorological situation at regular intervals. A meteorological model outputs winds fields, vertical profiles of temperature and humidity, and other physical parameters in a gridded structure that are physically self consistent and consistent with observations.

Comparisons of the model results with the meteorological observations will be made as part of the operational evaluation of the meteorological model. The simulated meteorological fields by MM5 in its fully predictive model will be compared with the results of MM5 simulations made with 4DDA and with the observations. The CCOS airborne and remote sensing upper-air measurements will be important for this comparison.

The modeled flow patterns for northern and central California will be compared with observations. Here it will be important to determine the optimum horizontal and vertical resolutions for air quality modeling applications. Aircraft observations will allow the elevated layers with specific stability and dynamics to be determined and compared with the stability and dynamics of the modeled layers.

On a smaller scale the detailed measurements of the vertical wind and temperature structure of the atmospheric boundary layer and the spatial characteristics of mixing depth for both convective and stable conditions will be compared with modeling results. The observed properties of land-sea breezes, urban circulations, local flows (slope and drainage), and diurnal variation of thermal stability and shear will be compared with model calculations.

Diagostic tests will include sensitivity tests of the input parameters, for example, topographic resolution, model grid, synoptic fields vs. radiosonde network, range and variation of sea/surface temperature, urban effects/roughness, sinks and sources of heat. This will allow an estimation of the relative importance of various meteorological processes and the uncertainties in model results.

1.5.2 Emission Inventories

The development of the emission inventory for air quality modeling of central California will be a major effort. The study domain is large and the required emission inventory should be highly detailed for CCOS modeling. The emission inventory needed to support the CCOS modeling will be a series of day-specific, hourly, gridded emission inventories that cover each day of the ozone episodes captured during the field study. There are about 30 districts in the CCOS modeling domain. Each local air district in the state updates a portion of the emission inventory for their area. To help coordinate this effort, the Emission Inventory Coordination Group (EICG) has been established to determine the process for preparing the emission inventories needed to support air quality modeling for CCOS. Participants in the group include many local air districts, several local councils of government, Caltrans, California Energy Commission, and the ARB. Local air districts participating to date include San Joaquin Valley Unified APCD, Bay Area AQMD, Sacramento Metropolitan AQMD, Mendocino County AQMD, Northern Sierra AQMD, Yolo-Solano AQMD, Placer County APCD, San Luis Obispo County APCD, and Monterey Bay Unified APCD. Other local air districts will also be participating. See Section 3.1.2 for details.

Evaluations of emission inventory estimates are an essential part of model performance evaluations. The application of continuous speciated VOC data in source apportionment offers insights regarding the temporal variations in source contributions that are difficult to discern from a limited number of canister samples that are integrated over a period of 3 hours or more. The diurnal and day-of-the-week variations in the measured relative and absolute levels of ozone precursors (NOx, CO and VOC) can be compared to corresponding values estimated by model simulations. Other related approaches for evaluation of emission inventories include: 1) performance evaluations of air quality simulation models; 2) spatial and temporal comparisons of ambient and emission inventory non-methane organic gas speciation profiles and pollutant ratios (e.g., CO/NOx and VOC/NOx); 3) comparisons of long-term trends in ambient pollutant concentrations and concentration ratios with emission inventory trends; 4) comparisons of on-road measurements with motor vehicle emission models; and 5) fuel-based inventory based on regional gasoline sales and fleet-averaged, fuel-based emission factors from remote sensing measurements. Details are in Section 3.2.2.

1.5.3 Air Quality Models

ARB, in coordination with Districts and the CCOS Technical Committee, will analyze the data collected during the CCOS field measurement program and will select a minimum of three ozone episodes to simulate. Assistance will be sought from air districts to develop day-specific emission inventory as well as additional simulation days. See Section 3.2 for details.

Air quality models consist of parameterizations of atmospheric chemical mechanisms, advection, photolysis, deposition and other atmospheric processes that affect the concentrations of air pollutants. The air quality model uses the output of the meteorological model and the emissions inventory as its input. The evaluation of the meteorological model and the emissions inventory is therefore important for the evaluation of the air quality model as discussed above.

Despite efforts to improve models during the past two decades, significant questions remain in both model formulation and input data. Uncertainties in the estimation of emissions are believed to one of the major limitations to producing reliable air quality model results. Studies during the past twelve years have shown that on-road reactive organic gases (ROG) and CO emissions have been historically underestimated (e.g., Ingalls, 1989; Pierson et al., 1990; Fujita et al., 1992). Sensitivity studies also showed that model performance was greatly improved when the base on-road motor vehicle ROG emissions were increased by substantial margins (Wagner and Wheeler, 1993; Chico et al., 1993; Harley et al., 1993). Gaps in model formulation that fail to treat certain chemical and physical processes adequately are additional limitations. Boundary-layer parameterizations that determine the rates of dilution and mixing, and the origin and evolution of ozone layers aloft are examples of such gaps. Other limitations include insufficient spatial and temporal data to adequately specify boundary conditions and photolytic rate parameters. Despite the limitations imposed by model uncertainties, air quality models remain the only acceptable tools available for quantitatively estimating the effect of control measures on future air quality.

The reliability of model outputs is assessed through operational and diagnostic evaluations and application of alternative diagnostic tools. Operational evaluations consist of comparing concentration estimates from the model to ambient measurements. The level of confidence that can be developed from this type of evaluation increases with the number and variety of episodes and chemical species that are examined. Measurements of the three-dimensional variations in ozone and ozone precursors also enhance the utility of the evaluations. Diagnostic evaluations determine if the model is estimating ozone concentrations correctly for the right reasons by assessing whether the physical and chemical processes within the model are simulated correctly. Examples of diagnostic tests include examining ratios of chemical species that are sensitive to specific processes within the model such as O_3/NOy, O_3/ NOz, examining the flux of ozone and ozone precursor across interbasin transport corridors, and comparing concentration changes from weekdays to weekends.

Operational Evaluation

The operational model evaluation will focus on the determination of the extent of agreement between simulated and measured concentrations of ozone and its precursors in their spatial distribution and timing. Model simulations will be compared with airborne measurements of VOCs (total VOC, homologous groups, and lumped VOC classes), along boundaries, above the mixed layer, and at the surface with measurements made at the research sites. A similar comparison will be made for the measurements of nitrogenous species concentrations. The temporal and spatial variability of the initial and boundary conditions will be evaluated to determine their effect on model output.

Diagnostic Evaluations

The diagnostic evaluation must evaluate a model's representations of gas-phase chemistry, photolysis rates, treatment of advection, deposition rates and the treatment of subgrid scale processes. The treatment of photolytic rate parameters will be evaluated by comparing the model default values with measurements. Comparisons of calculated secondary chemical product concentrations with measurements will be used to assess the chemical mechanisms. Other examples of chemical diagnostic tests include examining ratios of chemical species that are sensitive to specific processes within the model such as O_3/NOy, O_3/ NOz and comparing concentration changes from weekdays to weekends.

The process analysis of Jeffries and Tonnesen (1994) should be used to make a detailed mass balance for each simulation. This will allow the determination of the effect of each process on the concentrations of ozone and other air pollutants. Although it is not possible to use measurements to develop an independent, comprehensive mass balance throughout the study region, the measurements can be used to check key parameters within simulations. For example, the concentration ratio of NO to NO_2 or the concentration ratio of a highly reactive VOC to a less reactive VOC could be compared with the model results. Alternatively model calculated parameters such as HO could be used along with measured concentrations of VOC to estimate VOC to NOx ratios. Both approaches should provide strong tests of the conceptual model.

Diagnostic evaluation of the transport is more difficult but comparisons of the horizontal and vertical distributions of ozone and its precursors will be required. Another test to evaluate the transport would be to compare measured and modeled fluxes of ozone and ozone precursors across interbasin transport corridors.

1.5.4 Plume in Grid Module Evaluation

One of the most important issues for air quality modeling in CCOS is the treatment of plumes from elevated point sources containing high concentrations of NOx. Ozone formation rate in the plume of an elevated point source will be different from the ambient air because of their very different VOC/NOx ratios. Although many models ignore the effect of plumes by simply mixing the plume emissions into typical grid cell volumes, some air quality models use a plume-in-grid (PiG) approach. In the PiG approach a Gaussian-shaped plume is simulated in a Lagrangian reference frame that moves with the local wind vector, superimposed on the Eulerian reference frame of the host grid model, and at some suitable time period the contents of the plume are mixed into the grid cells. Most current approaches are overly dispersive and do not treat the effect of turbulence on chemistry and they ignore the effect of wind shear on plume separation.

A more advanced approach was developed under EPRI sponsorship, the Second order Closure Integrated PUFF model (SCIPUFF) with a chemistry module (SCICHEM). Their improved parameterizations of turbulent chemistry makes simulations more realistic than models using simpler approaches, particularly within the first few kilometers downwind of the smokestack, where plume confinement and turbulent chemistry have the greatest effect on local as well as overall ozone production. The SCICHEM was evaluated favorably as part of the 1995 Nashville/Middle Tennessee Ozone Study. Since the composition of the plumes will be different for central California, these new modules should be evaluate using the CCOS database.

1.6 Corroborative Data Analysis

Data analysis is an essential part of the database and model development components of CCOS. Measurements, by themselves, say nothing about the causes of air pollution and the likely effects of emission reductions. It is only when these measurements are interpreted that relationships can be observed and conclusions can be drawn. Similarly, mathematical models cannot be expected to explain phenomena that are not conceptually defined. "Conceptual models" of pollutant emissions, transport, chemical transformation, and deposition must be formed so that the best mathematical formulations can be selected to describe them. Section 3.3 provides details of tasks that address data analysis objectives.

The corroborative data analysis will determine if the conceptual model of ozone formation in central California and the models derived from it is sufficiently valid for policy development. It will involve all aspects of CCOS diagnostic data analysis and model evaluation. Corroborative data analysis will be used to reinforce current understanding, identify gaps and to improve the conceptual model of ozone formation. The corroborative data analysis will be used to provide a comprehensive picture of ozone formation that will be used to determine if measurement and modeling results are consistent with the conceptual model as revised by CCOS.

1.6.1 Contribution of Transported Pollutants to Ozone Violations in Downwind Areas

In principle, well-performing air quality modeling systems have the ability to quantify local and transported contributions to ozone exceedances in a receptor area. However, many of the interbasin transport couples in the CCOS study region involve complex flow patterns with strong terrain influences that are difficult to realistically simulate. The CCOS field campaign provides routine and supplemental measurements at locations where transport can occur. The proposed upper air network provides a “flux plane” method by which quantitative estimate is possible, with suitable assumptions. In combination with modeling, data analyses can improve the evaluation of modeling results and provide additional quantification of transport contributions.

Methods that should be applied include timing of ozone where morning peaks indicate fumigation of carry-over aloft, peaks near solar noon indicate possible local contributions, and delayed peaks indicate transport, with later times corresponding to sites further downwind along the transport path. Other methods include back trajectory wind analysis and examination of ratios of species (i.e., xylenes-to-benzene ratio). In addition, vertical planes intersecting the profiler sites downwind of and perpendicular to the transport path can be defined and provide estimates of transport through likely transport corridors. The analyses use surface and aircraft measurements of pollutant concentrations and surface, wind profiler, and aircraft meteorological data for volume flux estimations.

Tracer techniques, both active (intentional release) and passive (tracers of opportunity), were considered very early in the study, but were dismissed due to relatively high costs. However, source apportionment of hydrocarbons can be applied as a passive tracer technique, where potential hydrocarbon "fingerprints" are the tracers of opportunity. This method is also supported by the CCOS study plan, and corroboration with modeling results will be evaluated.

1.6.2 VOC Versus NOx Sensitivity

One of the most important questions for ozone control strategies is whether to focus on NOx or VOC control. To choose the proper control strategy it is necessary to know if ozone production is limited in a location more by the NOx or VOC available. Models and measurements have been applied to answer this question. One of the methods would be to determine ozone isopleths from measurements for each site in an airshed but usually not enough data are available. Therefore indicators for VOC or NOx limitation include ratios such as HNO_3/H_2O_2 and other ratios have been applied to both measurements and models. Within CCOS, NOx and VOC limitation will be investigated through the use of measurements, indicators and modeling analysis.

One of the most important tests of model simulations is the ability to simulate accurately weekday-weekend differences in precursors and ozone. One of the most important applications of this test is that it helps to probe the relative sensitivity of ozone concentrations to VOC and NOx. Since the mid-1970's it has been documented that ozone levels in California's South Coast Air Basin (SoCAB) are higher on weekends than on weekdays, in spite of the fact that ozone pollutant precursors are lower on weekends than on weekdays (Elkus and Wilson, 1977; Horie et al., 1979; Levitts and Chock, 1975; Zeldin et al., 1989; Blier and Winer, 1998; and Austin and Tran, 1999). Similar effects have been observed in San Francisco (Altshuler et al., 1995) and in the northeastern cities of Washington D.C., Philadelphia, and New York (SAIC, 1997). While a substantial "weekend effect" has been observed in these cities, the effect is less pronounced in Sacramento (Austin and Tran, 1999), and is often reversed in Atlanta (Walker, 1993) where VOC/NOx ratios are typically higher. Several of the above studies show that the "weekend effect" is generally less pronounced in downwind locations where ambient VOC/NOx ratios are higher.

Understanding the response of ozone levels to specific changes in VOC or NOx emissions is a fundamental prerequisite to developing a cost-effective ozone abatement strategy. The varying emissions that occur between weekday and weekend periods provide a natural test case for air quality simulation models. At the same time, the model performance and evaluation must be accompanied by an evaluation of the accuracy of the temporal and spatial patterns of precursor emissions. With the questions that still remain regarding the accuracy of emission inventories, the “weekend effect” emphasizes the need for observation-based data analysis to examine the relationship between ambient O3 and precursor emissions. The results of corroborative data analyses need to be reconciled with model outputs taking into consideration the various sources of uncertainties associated with both approaches.

The current conceptual model must be revisited and refined using the results yielded by the foregoing data analyses. New phenomena, if they are observed, must be conceptualized so that a mathematical model to describe them may be formulated and tested. The formulation, assumptions, and parameters in mathematical modules that will be included in the integrated air quality model must be examined with respect to their consistency with reality.

1.7 Funding

Cost estimates have been prepared for each element of the base and optional programs based on a consensus of the CCOS Technical Committee. Cost estimates are summarized in Table 5-1 for major components of the proposed measurement plan. The total contract costs for CCOS is $7,200,000.

In addition to the above contract costs, the ARB and the local APCD’s are committing in-kind resources for planning and execution of CCOS. In-kind costs include additional efforts that are specifically required during CCOS (e.g., project management, episode forecast, site operations, quality assurance, emission inventory development, and data management) and does not include data collection and analysis associated with normal daily operations (e.g., PAMS and other aerometric monitoring programs). The in-kind costs for the field study portion of CCOS total $1,400,000, which does not include substantial leveraging of resources that will be available from CRPAQS. Additional in-kind resources will be committed for modeling and data analysis.